

ANSI/ABMA 12.1:1992 (Stabilized Maintenance 2010)

AMERICAN NATIONAL STANDARD

*Accredited Standards
Committee B3*



Load Instrument Ball Bearings Metric Design ANSI/ABMA 12.1:1992

Secretariat

American Bearing
Manufacturers Association

ANSI/ABMA 12.1:1992

Stabilized Maintenance 2010



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AMERICAN NATIONAL STANDARD

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METRIC DESIGN

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Instrument Ball Bearings

Metric Design

1. SCOPE

1.1 This standard covers the characteristics that define metric design instrument ball bearings, their boundary dimensions, tolerances, internal clearances, classification for selective assembly, and recommended practices for gaging, friction torque determination, load rating, operational life prediction and yield rate limitation.

1.2 The standard applies only to the size ranges covered by Paragraph 4, Boundary Dimensions.

2. CHARACTERISTICS

2.1 Instrument ball bearings comprise bearings with functional requirements for use in any unit that can, in a general sense, be characterized as an instrument.

2.2 Instrument ball bearings must be particularly free from foreign matter and are typically applied to meet one or more of the following characteristics:

- a. Positional accuracy.
- b. Low friction torque.
- c. Smoothness of operation.
- d. Yield rate limitation.

Due to the many specialized requirements that exist in instrument applications, specifications for these characteristics should be established only after full agreement between the manufacturer and the user.

2.3 Instrument precision ball bearings meet tolerances specified in Classes ABEC 5P, ABEC 7P, ABEC 9P, ABEC 5T and ABEC 7T and may reflect specific requirements against one or more of the characteristics of Paragraph 2.2 above.

2.4 Instrument semi-precision ball bearings meet tolerances specified in Class ABEC 3P.

3. SYMBOLS

THE SYMBOLS USED IN THIS STANDARD HAVE THE FOLLOWING MEANINGS:

d	= bearing bore diameter, basic
d_s	= single bore diameter
Δ_{ds}	= deviation of a single bore diameter (difference between a single diameter and the basic diameter)
V_{ds}	= bore diameter variation (difference between the largest and the smallest actual single bore diameters of one individual ring)
d_m	= mean bore diameter (arithmetical mean of the largest and the smallest actual single bore diameters of one individual ring)
Δ_{dm}	= mean bore diameter deviation (difference between the mean bore diameter and the basic bore diameter)
d_{mp}	= single plane mean bore (arithmetical mean of the largest and the smallest actual single a single radial plane)
Δ_{dmp}	= single plane mean bore diameter deviation (difference between a single plane mean bore diameter and the basic bore diameter)
V_{dp}	= bore diameter variation in a single radial plane (difference between the largest and the smallest actual single bore diameters in a single radial plane)
V_{dmp}	= mean bore diameter variation (difference between the largest and the smallest actual single plane mean bore diameters of one individual ring)
D	= bearing outside diameter, basic
D_s	= single outside diameter
Δ_{Ds}	= deviation of a single outside diameter (difference between a single outside diameter and the basic outside diameter)
V_{Ds}	= outside diameter variation (difference between the largest and the smallest actual single outside diameters of one individual ring)
D_m	= mean outside diameter (arithmetical mean of the largest and the smallest actual single outside diameters of one individual ring)
Δ_{Dm}	= mean outside diameter deviation (difference between the mean outside diameter and the basic outside diameter)
D_{mp}	= single plane mean outside diameter (arithmetical mean of the largest and the smallest actual single outside diameters in a single radial plane)
Δ_{Dmp}	= single plane mean outside diameter deviation (difference between a single plane mean outside diameter and the basic outside diameter)
V_{Dp}	= outside diameter variation in a single radial plane (difference between the largest and the smallest actual single outside diameters in a single radial plane)
V_{Dpm}	= mean outside diameter variation (difference between the largest and the smallest actual single plane mean outside diameters of one individual ring)

3. SYMBOLS – continued

B	= inner ring width, basic
C	= outer ring width, basic
B _s or C _s	= single ring width (distance between the points of intersection of the two actual side faces of a ring and a straight line perpendicular to the plane tangential to the reference face of the ring)
ΔB _s or ΔC _s	= deviation of a single ring width (difference between a single ring width and the basic ring width)
V _{Bs} or V _{Cs}	= ring width variation (difference between the largest and the smallest actual single width of one individual ring)
B _m or C _m	= mean ring width (arithmetical mean of the largest and the smallest actual ring widths of one individual ring)
K _i	= inner ring raceway to bore thickness variation (difference between the largest and the smallest radial distance between the bore surface and the middle of a raceway on the outside of the ring)
K _e	= outer ring raceway to outside surface thickness variation (difference between the largest and the smallest radial distance between the outside surface and the middle of a raceway on the inside of the ring)
S _{d1}	= variation of inside surface generatrix inclination with inner ring reference face (backface). (This variation was previously called bore runout with side)
S _D	= variation of outside surface generatrix inclination with outer ring reference face (backface). (This variation was previously called outside surface runout with reference side)
S _i or S _e	= raceway parallelism with face (difference between the largest and the smallest axial distance between the plane tangential to the reference face and the middle of the raceway)
D ₁	= outer ring flange outside diameter, basic
ΔD _{1s}	= deviation of a single flange outside diameter
C ₁	= outer ring flange width, basic
ΔC _{1s}	= deviation of a single width of the outer ring flange
V _{C1}	= outer ring flange width variation
S _{e1}	= flange back face (locating face) runout with raceway (groove)
a ₁	= Life adjustment factor for reliability
a ₂	= Life adjustment factor for material
a ₃	= Life adjustment factor for application conditions
B _t	= Total raceway curvature = $f_i + f_o - 1$

3. SYMBOLS – continued

C	= Basic load rating
Cor	= Basic static radial load rating
Coa	= Basic static axial load rating
d _p	= Bearing pitch diameter
D _w	= Ball diameter
f _{cm}	= a factor which depends on the geometry of the bearing components, the accuracy to which the various components are made and contemporary, normally used material and its manufacturing quality
f _i	= raceway curvature ratio, inner ring = $\frac{r_i}{D_w}$
f _o	= raceway curvature ratio, outer ring = $\frac{r_o}{D_w}$
F _a	= Axial or thrust load
F _r	= Radial load
G _r	= Radial internal clearance
G _a	= Axial internal clearance
h _{min}	= Minimum shaft shoulder diameter
H _{max}	= Maximum housing shoulder diameter
i	= Number of rows of rolling elements in a bearing
L	= Bearing life
L _n	= Bearing rating life
P _r	= Dynamic equivalent radial load
Por	= Static equivalent radial load
Poa	= Static equivalent axial load
r _{s min}	= Smallest single chamfer dimension
r _{1s min}	= Smallest single chamfer dimension for the non-thrust side of angular contact bearing rings, the non-flanged side of flanged outer rings and abutting faces of duplex ground pairs of bearings
r _i	= Raceway radius, inner ring
r _o	= Raceway radius, outer ring
X	= Radial load factor for life calculation

3. SYMBOLS – continued

Y	= Axial load factor for life calculation
Z	= Number of balls
α_o	= Initial (zero load) contact angle
α_t	= Operating contact angle

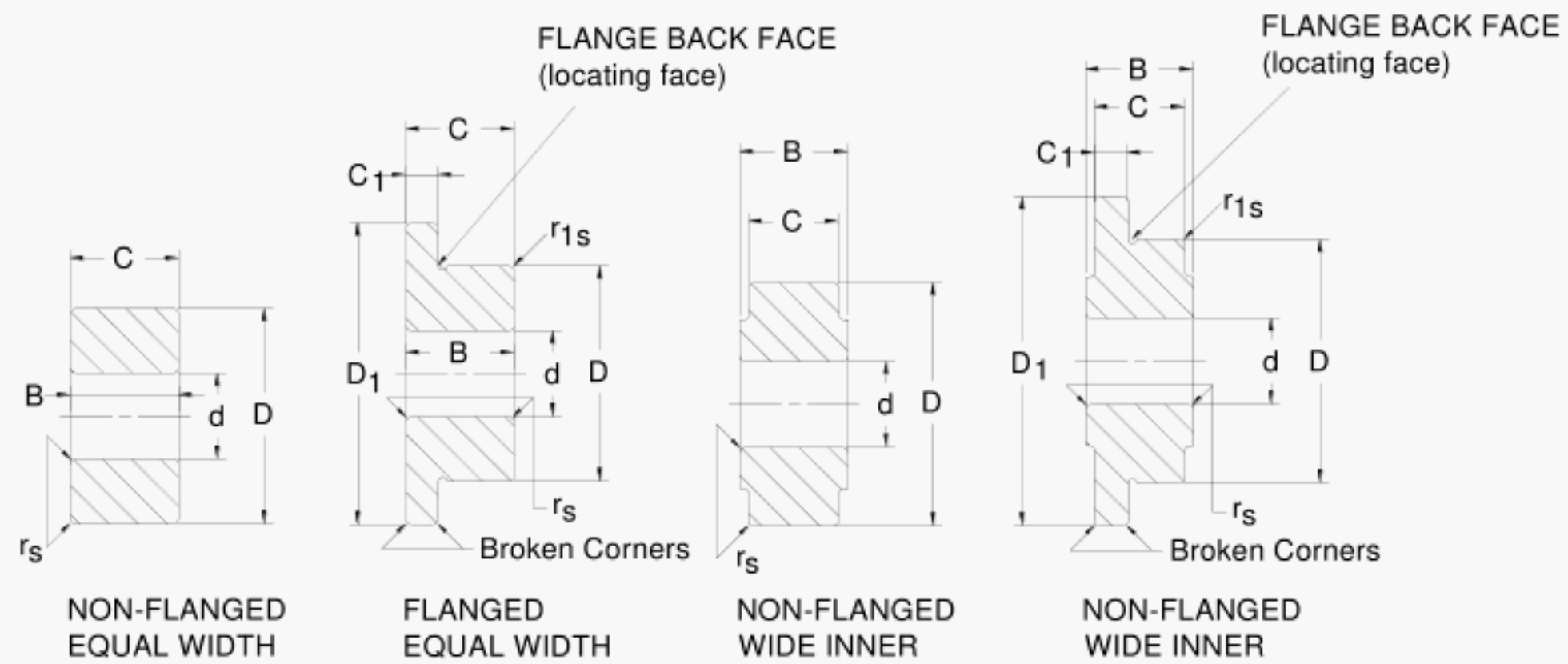
4. BOUNDARY DIMENSIONS

4.1 Boundary dimensions for standard sizes of instrument ball bearings are shown in Tables 4.1 through 4.3.

5. TOLERANCES

5.1 Tolerances applicable to bearings listed in Tables 4.1 through 4.3 are shown in Tables 5.1 through 5.6. These tolerances also apply to instrument ball bearings with nonstandard boundary dimensions which fall within the size ranges covered in Section 4.

TABLE 4.1 — Part 1
BOUNDARY DIMENSIONS
INSTRUMENT BALL BEARINGS
METRIC DESIGN



Dimensions in mm

DIAMETERS — ALL			WIDTHS — OPEN BEARINGS			WIDTHS — SHIELDED BEARINGS			CHAMFER*	
Bore	O.D.	Flange O.D.	Equal Width Rings	Wide Inner	Flange	Equal Width Rings	Wide Inner	Flange		
d	D	D_1	$B \text{ \& } C$	B	C_1	$B \text{ \& } C$	B	C_1	$r_s \text{ min.}$	$r_{1s} \text{ min.}^{**}$
1.5	4.0	5.0	1.2	2.2	0.4	2.0	3.0	0.6	0.05	0.05
1.5	5.0	6.5	2.0	3.0	0.6	2.6	3.6	0.8	0.15	0.08
2.0	5.0	6.1	1.5	2.5	0.5	2.3	3.3	0.6	0.08	0.05
2.0	6.0	7.5	2.3	3.3	0.6	3.0	4.0	0.8	0.15	0.08
2.5	6.0	7.1	1.8	2.8	0.5	2.6	3.6	0.8	0.08	0.05
2.5	7.0	8.5	2.5	3.5	0.7	3.5	4.5	0.9	0.15	0.08
3.0	7.0	8.1	2.0	3.0	0.5	3.0	4.0	0.8	0.10	0.05
3.0	8.0	9.5	3.0	4.0	0.7	4.0	5.0	0.9	0.15	0.08
3.0	10.0	11.5	4.0	5.0	1.0	4.0	5.0	1.0	0.15	0.08
4.0	9.0	10.3	2.5	3.5	0.6	4.0	5.0	1.0	0.10	0.05
4.0	11.0	12.5	4.0	5.0	1.0	4.0	5.0	1.0	0.15	0.08
4.0	13.0	15.0	5.0	6.0	1.0	5.0	6.0	1.0	0.20	0.10
4.0	16.0	18.0	5.0	6.0	1.0	5.0	6.0	1.0	0.30	0.15
5.0	11.0	12.5	3.0	4.0	0.8	5.0	6.0	1.0	0.15	0.08
5.0	13.0	15.0	4.0	5.0	1.0	4.0	5.0	1.0	0.20	0.10
5.0	16.0	18.0	5.0	6.0	1.0	5.0	6.0	1.0	0.30	0.15
5.0	19.0	22.0	6.0	7.0	1.5	6.0	7.0	1.5	0.30	0.15
6.0	13.0	15.0	3.5	4.5	1.0	5.0	6.0	1.1	0.15	0.08
6.0	15.0	17.0	5.0	6.0	1.2	5.0	6.0	1.2	0.20	0.10
6.0	19.0	22.0	6.0	7.0	1.5	6.0	7.0	1.5	0.30	0.15
7.0	14.0	16.0	3.5	4.5	1.0	5.0	6.0	1.1	0.15	0.08
7.0	17.0	19.0	5.0	6.0	1.2	5.0	6.0	1.2	0.30	0.15
7.0	19.0	22.0	6.0	7.0	1.5	6.0	7.0	1.5	0.30	0.15
7.0	22.0	25.0	7.0	8.0	1.5	7.0	8.0	1.5	0.30	0.15
8.0	16.0	18.0	4.0	5.0	1.0	6.0	7.0	1.3	0.20	0.10
8.0	19.0	22.0	6.0	7.0	1.5	6.0	7.0	1.5	0.30	0.15
8.0	22.0	25.0	7.0	8.0	1.5	7.0	8.0	1.5	0.30	0.15
8.0	24.0	26.0	8.0	9.0	2.0	—	—	—	0.30	0.15
9.0	17.0	19.0	4.0	5.0	1.0	6.0	7.0	1.3	0.20	0.10
9.0	20.0	23.0	6.0	7.0	1.5	6.0	7.0	1.5	0.30	0.15
9.0	24.0	27.0	7.0	8.0	1.5	7.0	8.0	1.5	0.30	0.15
9.0	26.0	28.0	8.0	9.0	2.0	8.0	9.0	2.0	0.30	0.15

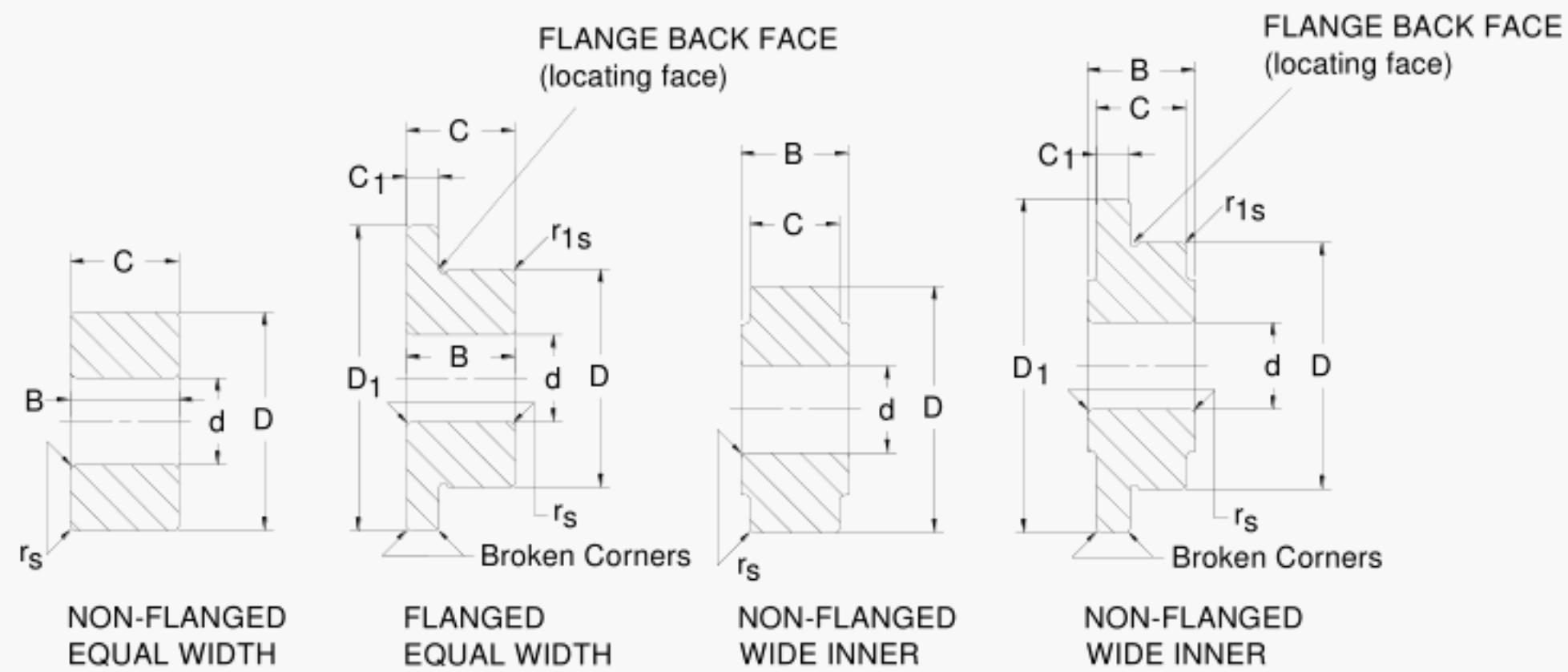
* The chamfer on bearings will clear a maximum fillet radius equal to the minimum chamfer shown (shaft or housing, as appropriate).

** For the narrow face of rings of angular contact bearings, the back face of flanged outer rings and abutting faces of ground pairs of bearings

r_{1s} min. applies.

NOTE: The shape of the bearing corner is not specified.

TABLE 4.1 — Part 2
BOUNDARY DIMENSIONS
INSTRUMENT BALL BEARINGS
METRIC DESIGN



Dimensions in inches

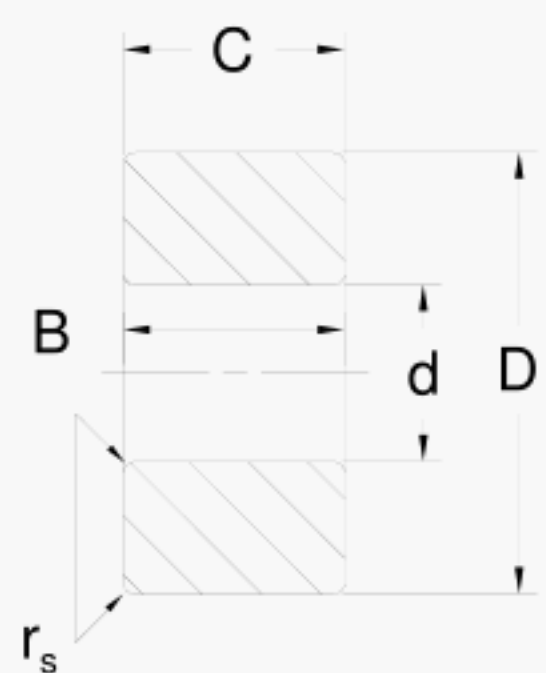
DIAMETERS — ALL			WIDTHS — OPEN BEARINGS			WIDTHS — SHIELDED BEARINGS			CHAMFER*	
Bore	O.D.	Flange O.D.	Equal Width Rings	Wide Inner	Flange	Equal Width Rings	Wide Inner	Flange		
d	D	D ₁	B & C	B	C ₁	B & C	B	C ₁	r _s min.	r _{1s} min.**
0.059 06	0.157 48	0.1969	0.0472	0.0866	0.0157	0.0787	0.1181	0.0236	0.002	0.002
0.059 06	0.196 85	0.2559	0.0787	0.1181	0.0236	0.1024	0.1417	0.0315	0.006	0.003
0.078 74	0.196 85	0.2402	0.0591	0.0984	0.0197	0.0906	0.1 299	0.0236	0.003	0.002
0.078 74	0.236 22	0.2953	0.0906	0.1299	0.0236	0.1181	0.1575	0.0315	0.006	0.003
0.098 43	0.236 22	0.2795	0.0709	0.1102	0.0197	0.1024	0.1417	0.0315	0.003	0.002
0.098 43	0.275 59	0.3346	0.0984	0.1378	0.0276	0.1378	0.1772	0.0354	0.006	0.003
0.118 11	0.275 59	0.3189	0.0787	0.1181	0.0197	0.1181	0.1575	0.0315	0.004	0.002
0.118 11	0.314 96	0.3740	0.1181	0.1575	0.0276	0.1575	0.1969	0.0354	0.006	0.003
0.118 11	0.393 70	0.4528	0.1575	0.1969	0.0394	0.1575	0.1969	0.0394	0.006	0.003
0.157 48	0.354 33	0.4055	0.0984	0.1378	0.0236	0.1575	0.1969	0.0394	0.004	0.002
0.157 48	0.433 07	0.4921	0.1575	0.1969	0.0394	0.1575	0.1969	0.0394	0.006	0.003
0.157 48	0.511 81	0.5906	0.1969	0.2362	0.0394	0.1969	0.2362	0.0394	0.008	0.004
0.157 48	0.629 92	0.7087	0.1969	0.2362	0.0394	0.1969	0.2362	0.0394	0.012	0.006
0.196 85	0.433 07	0.4921	0.1181	0.1575	0.0315	0.1969	0.2362	0.0394	0.006	0.003
0.196 85	0.511 81	0.5906	0.1575	0.1969	0.0394	0.1575	0.1969	0.0394	0.008	0.004
0.196 85	0.629 92	0.7087	0.1969	0.2362	0.0394	0.1969	0.2362	0.0394	0.012	0.006
0.196 85	0.748 03	0.8661	0.2362	0.2756	0.0591	0.2362	0.2756	0.0591	0.012	0.006
0.236 22	0.511 81	0.5906	0.1378	0.1772	0.0394	0.1969	0.2362	0.0433	0.006	0.003
0.236 22	0.590 55	0.6693	0.1969	0.2362	0.0472	0.1969	0.2362	0.0472	0.008	0.004
0.236 22	0.748 03	0.8661	0.2362	0.2756	0.0591	0.2362	0.2756	0.0591	0.012	0.006
0.275 59	0.551 18	0.6299	0.1378	0.1772	0.0394	0.1969	0.2362	0.0433	0.006	0.003
0.275 59	0.669 29	0.7480	0.1969	0.2362	0.0472	0.1969	0.2362	0.0472	0.012	0.006
0.275 59	0.748 03	0.8661	0.2362	0.2756	0.0591	0.2362	0.2756	0.0591	0.012	0.006
0.275 59	0.866 14	0.9843	0.2756	0.3150	0.0591	0.2756	0.3150	0.0591	0.012	0.006
0.314 96	0.629 92	0.7087	0.1575	0.1969	0.0394	0.2362	0.2756	0.0512	0.008	0.004
0.314 96	0.748 03	0.8661	0.2362	0.2756	0.0591	0.2362	0.2756	0.0591	0.012	0.006
0.314 96	0.866 14	0.9843	0.2756	0.3150	0.0591	0.2756	0.3150	0.0591	0.012	0.006
0.314 96	0.944 88	1.0236	0.3150	0.3543	0.0787	—	—	—	0.012	0.006
0.354 33	0.669 29	0.7480	0.1575	0.1969	0.0394	0.2362	0.2756	0.0512	0.008	0.004
0.354 33	0.787 40	0.9055	0.2362	0.2756	0.0591	0.2362	0.2756	0.0591	0.012	0.006
0.354 33	0.944 88	1.0630	0.2756	0.3150	0.0591	0.2756	0.3150	0.0591	0.012	0.006
0.354 33	1.023 62	1.1024	0.3150	0.3543	0.0787	0.3150	0.3543	0.0787	0.012	0.006

* The chamfer on bearings will clear a maximum fillet radius equal to the minimum chamfer shown (shaft or housing, as appropriate).

** For the narrow face of rings of angular contact bearings, the back face of flanged outer rings and abutting faces of ground pairs of bearings r_{1s} min applies.

NOTE: The shape of the bearing corner is not specified.

TABLE 4.2
BOUNDARY DIMENSIONS
INSTRUMENT BALL BEARINGS
EXTRA THIN SERIES
METRIC DESIGN



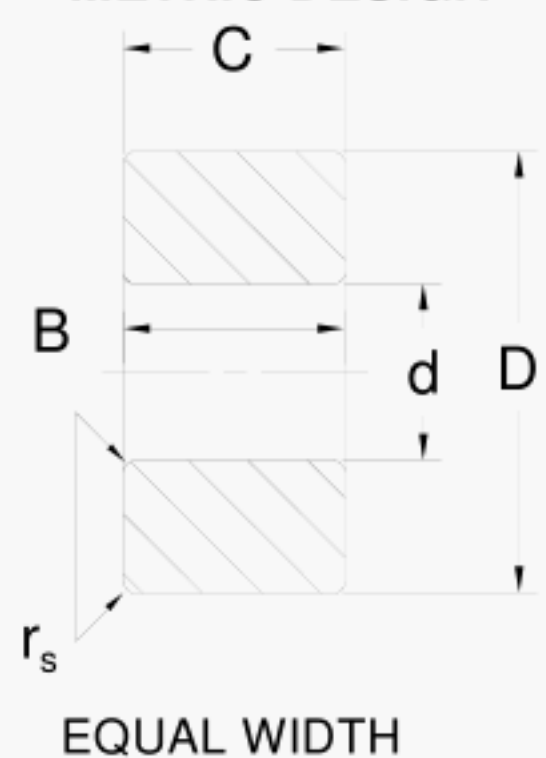
EQUAL WIDTH

Part 1		Dimensions in mm		
DIAMETERS		WIDTH	CHAMFER*	
BORE	O.D.			
d	D	B & C	r _s min.	r _{1s} min **
10	15	4.5	0.2	0.1
12	18	5	0.2	0.1
15	21	5	0.2	0.1
17	23	5	0.2	0.1
20	27	5	0.2	0.1
25	32	5	0.2	0.1
30	37	5	0.2	0.1

Part 2		Dimensions in inches		
DIAMETERS		WIDTH	CHAMFER*	
BORE	O.D.			
d	D	B & C	r _s min.	r _{1s} min **
0.393 70	0.590 55	0.1770	0.008	0.004
0.472 44	0.708 66	0.1969	0.008	0.004
0.590 55	0.826 77	0.1969	0.008	0.004
0.669 29	0.905 51	0.1969	0.008	0.004
0.787 40	1.602 99	0.1969	0.008	0.004
0.984 25	1.259 84	0.1969	0.008	0.004
1.181 10	1.456 69	0.1969	0.008	0.004

* The chamfer on bearings will clear a maximum fillet radius equal to the minimum chamfer shown (shaft or housing, as appropriate).
 ** For the narrow face of rings of angular contact bearings and abutting faces of duplex ground pairs of bearings, r_{1s} min applies.
NOTE: The shape of the bearing corner is not specified.

**TABLE 4.3
BOUNDARY DIMENSIONS
INSTRUMENT BALL BEARINGS
THIN SERIES
METRIC DESIGN**



Part 1		Dimensions in mm		
DIAMETERS		WIDTH	CHAMFER*	
BORE	O.D.			
d	D	B & C	r _s min.	r _{1s} min **
20	32	7	0.3	0.15
25	37	7	0.3	0.15
30	42	7	0.3	0.15
35	47	7	0.3	0.15
40	52	7	0.3	0.15
50	65	7	0.3	0.15
60	78	10	0.3	0.15
70	90	10	0.6	0.3
80	100	10	0.6	0.3

Part 2		Dimensions in inches		
DIAMETERS		WIDTH	CHAMFER*	
BORE	O.D.			
d	D	B & C	r _s min.	r _{1s} min **
0.787 40	1.259 84	0.2756	0.012	0.006
0.984 25	1.456 69	0.2756	0.012	0.006
1.181 10	1.653 54	0.2756	0.012	0.006
1.371 95	1.850 39	0.2756	0.012	0.006
1.574 80	2.047 24	0.2756	0.012	0.006
1.968 50	2.559 05	0.2756	0.012	0.006
2.362 20	3.070 86	0.3937	0.012	0.006
2.755 91	3.543 30	0.3937	0.024	0.012
3.149 61	3.937 01	0.3937	0.024	0.012

* The chamfer on bearings will clear a maximum fillet radius equal to the minimum chamfer shown (shaft or housing, as appropriate).
 ** For the narrow face of rings of angular contact bearings and abutting faces of duplex ground pairs of bearings, r_{1s} min applies.
NOTE: The shape of the bearing corner is not specified.

TABLE 5.1 — Part 1
TOLERANCE CLASS 3P
METRIC DESIGN

INNER RING								
Dimensions in mm Tolerances in micrometres								
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation		Radial Runout	Single Width Deviation	
d		Δ_{dm} (2)		Δ_{ds}		K_j	ΔB_s (1)	
Over	Incl.	High	Low	High	Low	Max.	High	Low
0	10	0	-5	+2.5	-7.5	5	0	-125

OUTER RING															Dimensions in mm	
															Tolerances in micrometres	
Outside Diameter		Mean Outside Diameter Deviation		OPEN BEARINGS		SHIELDED BEARINGS		Radial Runout	Single Width Deviation		Single Flange Outside Diameter Deviation		Single Flange Width Deviation			
				Single Outside Diameter Deviation		Single Outside Diameter Deviation										
D		Δ_{Dm} (2)		Δ_{Ds}		Δ_{Ds}		K_e	Δ_{Cs} (1)		Δ_{D1s}		Δ_{C1s}			
Over	Incl.	High	Low	High	Low	High	Low	Max.	High	Low	High	Low	High	Low		
0	18	0	-7.5	+2.5	-10	+5	-12	10	0	-125	+125	-50	0	-50		
18	30	0	-7.5	+2.5	-10	+5	-12	10	0	-125	+125	-50	0	-50		

NOTES:

- (1) Width deviation of duplex pairs is +0 -500 micrometres.
For additional bearings, deviation is proportional to number of bearings.
- (2) The use of Δ_{dm} and Δ_{Dm} for Tolerance Class 3P instead of Δ_{dmp} and Δ_{Dmp} is intentional.
Applicable to Instrument Ball Bearings, Inch Design, Table 4.1 Part 1.

TABLE 5.1 — Part 2
TOLERANCE CLASS 3P
METRIC DESIGN

INNER RING		Dimensions in inches Tolerances in 0.0001 inch (3)						
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation		Radial Runout	Single Width Deviation	
d		Δ_{dm} (2)		Δ_{ds}		K_j	ΔB_s (1)	
Over	Incl.	High	Low	High	Low	Max.	High	Low
0	0.39370	0	-2	+1	-3	2	0	+49

OUTER RING										Dimensions in inches Tolerances in 0.0001 inch (3)					
Outside Diameter		Mean Outside Diameter Deviation		OPEN BEARINGS		SHIELDED BEARINGS		Radial Runout	Single Width Deviation		Single Flange Outside Diameter Deviation		Single Flange Width Deviation		
				Single Outside Diameter Deviation		Single Outside Diameter Deviation									
D		Δ_{Dm} (2)		Δ_{Ds}		Δ_{Ds}		K_e	Δ_{Cs}		Δ_{D1s}		Δ_{C1s}		
Over	Incl.	High	Low	High	Low	High	Low	Max.	High	Low	High	Low	High	Low	
0	0.70866	0	-3	+1	-3.9	+2	-4.7	3.9	0	49	+49	-20	0	-20	
0.70866	1.18110	0	-3	+1	-3.9	+2	-4.7	3.9	0	49	+49	-20	0	-20	

NOTES:

(1) Width deviation of duplex pairs is +0 -197 (0.0001 inch). For additional bearings, deviation is proportional to number of bearings.

(2) The use of Δ_{dm} and Δ_{Dm} for Tolerance Class 3P instead of Δ_{dmp} and Δ_{Dmp} is intentional.

(3) Tolerances shown are calculated from primary metric tolerances given in Table 5.1 Part 1. Conversion has been carried out far enough to yield equivalent values.

Applicable to Instrument Ball Bearings, Metric Design, Tables 4.1 Part 2.

TABLE 5.2 — Part 1
TOLERANCE CLASS 5P
METRIC DESIGN

INNER RING												Dimension in mm							
												Tolerances in micrometres							
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation		Single Bore Dia. Variation		Mean Bore Dia. Variation		Radial Runout		Bore Runout with Ref. Side		Raceway Runout with Ref. Side		Single Width Deviation		Width Variation	
d		Δ_{dmp}		Δ_{ds}		V_{dp}		V_{dmp}		K_i		S_{di}		S_i		ΔB_s (1)		VB_s	
Over	Incl.	High	Low	High	Low	Max.	Max.	Max.	Max.	Max.	Max.	Max.	Max.	High	Low	Max.	Max.	Max.	Max.
0	10	0	-5	0	-5	2.5	2.5	3.5	7	7	7	7	7	0	-25	5	5	5	5

OUTER RING																								Dimension in mm				Tolerances in micrometres			
Outside Diameter		Mean Outside Diameter Deviation		OPEN BEARINGS				SHIELDED BEARINGS				Radial Runout	O.D. Cylindrical Surface Runout With Ref. Side	Raceway Runout With Ref. Side	Single Width Deviation		Width Variation	OUTER RING FLANGE													
				Single Outside Diameter Deviation		Mean Outside Dia. Variation		Single Outside Diameter Deviation		Mean Outside Dia. Variation								Single Flange Outside Diameter Deviation		Single Flange Width Deviation		Flange Width Variation		Raceway Runout With Flange Face							
D		Δ_{Dmp}		Δ_{Ds}		V_{Dp}	V_{Dmp}	Δ_{Ds}		V_{Dp}	V_{Dmp}	K_e	S_D	S_e	ΔC_s (1)		VC_s	ΔD_{fs}		ΔC_{fs}		VC_f	S_{ef}								
Over	Incl.	High	Low	High	Low	Max.	Max.	High	Low	Max.	Max.	Max.	Max.	Max.	High	Low	Max.	High	Low	High	Low	Max.	Max.								
0	18	0	-5	0	-5	2.5	2.5	+1	-6	5	5	5	8	8	0	-25	5	0	-25	0	-50	5	10								
18	30	0	-6	0	-6	2.5	2.5	+1	-7	5	5	6	8	8	0	-25	5	0	-25	0	-50	5	10								

NOTES:

- (1) Width deviation duplex is +0 -400 micrometres.
For additional bearings, deviation is proportional to number of bearings.

Applicable to Instrument Ball Bearings, Metric Design, Table 4.1 Part 1

TABLE 5.2 — Part 2
TOLERANCE CLASS 5P
METRIC DESIGN

INNER RING													Dimension in inches Tolerances in 0.0001 inch (2)	
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation		Single Bore Dia. Variation	Mean Bore Dia. Variation	Radial Runout	Bore Runout With Ref. Side	Raceway Runout With Ref. Side	Single Width Deviation		Width Variation	
d		Δ_{dmp}		Δ_{ds}		V_{dp}	V_{dmp}	K_i	S_{di}	S_i	ΔB_s (1)		VB_s	
Over	Incl.	High	Low	High	Low	Max.	Max.	Max.	Max.	Max.	High	Low	Max.	
0	0.39370	0	-2	0	-2	1	1	1.4	2.8	2.8	0	-9.8	2	

OUTER RING

Dimension in inches

Tolerances in 0.0001 inch (2)

Outside Diameter		Mean Outside Diameter Deviation		OPEN BEARINGS				SHIELDED BEARINGS				Radial Runout	O.D. Cylindrical Surface Runout With Ref. Side	Raceway Runout With Ref. Side	Single Width Deviation		Width Variation	OUTER RING FLANGE					
				Single Outside Diameter Deviation		Mean Outside Dia. Variation	Single Outside Dia. Variation	Single Outside Diameter Deviation	Mean Outside Dia. Variation	Single Outside Dia. Variation	Single Flange Outside Diameter Deviation							Single Flange Width Deviation	Flange Width Variation	Raceway Runout With Flange Face			
D		Δ_{Dmp}		Δ_{Ds}		V_{Dp}	V_{Dmp}	Δ_{Ds}		V_{Dp}	V_{Dmp}	K_e	S_D	S_e	ΔC_s (1)		VC_s	ΔD_{fs}		ΔC_{fs}		VC_f	S_{ft}
Over	Incl.	High	Low	High	Low	Max.	Max.	High	Low	Max.	Max.	Max.	Max.	Max.	High	Low	Max.	High	Low	High	Low	Max.	Max.
0	0.70866	0	-2	0	-2	1	1	+0.4	-2.4	2	2	2	3	3	0	-9.8	2	0	-9.8	0	-19.7	2	4
0.70866	1.18110	0	-2.4	0	-2.4	1	1	+0.4	-2.8	2	2	2.4	3	3	0	-9.8	2	0	-9.8	0	-19.7	2	4

- NOTES:
- (1) Width deviation duplex is +0 -150 (0.0001 Inch).
For additional bearings, deviation is proportional to number of bearings.
- (2) Tolerance shown are calculated from primary metric tolerances given in Table 5.2 Part 1. Conversion has been carried out far enough to yield equivalent values.
- Applicable to Instrument Ball Bearings, Metric Design, Table 4.1 Part 2

TABLE 5.3 — Part 1
TOLERANCE CLASS 7P
METRIC DESIGN

INNER RING														Dimension in mm						Tolerances in micrometres																			
Bore Diameter				Mean Bore Diameter Deviation				Single Bore Diameter Deviation				Single Bore Dia. Variation				Mean Bore Dia. Variation				Radial Runout				Bore Runout With Ref. Side				Raceway Runout With Ref. Side				Single Width Deviation				Width Variation			
d				Δ_{dmp}				Δ_{ds}				V_{dp}				V_{dmp}				K_i				S_{di}				S_i				$\Delta B_s(1)$				VB_s			
Over		Incl.		High	Low			High	Low			Max.	Max.			Max.	Max.			Max.	Max.			Max.	Max.			High	Low			Max.							
0		10		0	-5			0	-5			2.5	2.5			2.5	2.5			2.5	3			3	3			0	-25			2.5							

OUTER RING																										Dimension in mm		Tolerances in micrometres	
Outside Diameter		Mean Outside Diameter Deviation		OPEN BEARINGS				SHIELDED BEARINGS				Radial Runout		O.D. Cylindrical Surface Runout With Ref. Side		Raceway Runout With Ref. Side		Single Width Deviation		Width Variation		OUTER RING FLANGE							
				Single Outside Diameter Deviation		Mean Outside Dia. Variation		Single Outside Dia. Variation		Single Flange Width Deviation												Flange Width Variation		Raceway Runout With Flange Face					
D		Δ_{Dmp}		Δ_{Ds}		V_{Dp}		V_{Dmp}		Δ_{Ds}		K_e		S_D		S_e		$\Delta C_s(1)$		VC_s		ΔD_{fs}		ΔC_{fs}		VC_f		S_{ef}	
Over	Incl.	High	Low	High	Low	Max.	Max.	High	Low	Max.	Max.	Max.	Max.	Max.	Max.	High	Low	Max.	Max.	High	Low	High	Low	High	Low	Max.	Max.	Max.	Max.
0	18	0	-5	0	-5	2.5	2.5	+1	-6	5	5	3.5	4	5	5	0	-25	2.5	2.5	0	-25	0	-50	2.5	8	8	8	8	
18	30	0	-5	0	-5	2.5	2.5	+1	-6	5	5	4	4	5	5	0	-25	2.5	2.5	0	-25	0	-50	2.5	8	8	8	8	

NOTES:

(1) Width deviation duplex is +0 -400 micrometres.
For additional bearings, deviation is proportional to number of bearings.

Applicable to Instrument Ball Bearings, Metric Design, Table 4.1 Part 1

TABLE 5.3 — Part 2
TOLERANCE CLASS 7P
METRIC DESIGN

INNER RING													Dimension in inches Tolerances in 0.0001 inch (2)	
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation		Single Bore Dia. Variation	Mean Bore Dia. Variation	Radial Runout	Bore Runout with Ref. Side	Raceway Runout with Ref. Side	Single Width Deviation		Width Variation	
d		Δ_{dmp}		Δ_{ds}		V_{dp}	V_{dmp}	K_i	S_{di}	S_i	ΔB_s (1)		VB_s	
Over	Incl.	High	Low	High	Low	Max.	Max.	Max.	Max.	Max.	High	Low	Max.	
0	0.3937	0	-2	0	-2	1	1	1	1.2	1.2	0	-9.8	1	

OUTER RING

Dimension in inches
Tolerances in 0.0001 inch (2)

Outside Diameter	Mean Outside Diameter Deviation	OPEN BEARINGS				SHIELDED BEARINGS				Radial Runout	O.D. Cylindrical Surface Runout With Ref. Side	Raceway Runout With Ref. Side	Single Width Deviation		Width Variation	OUTER RING FLANGE							
		Single Outside Diameter Deviation		Mean Outside Dia. Variation	Single Outside Dia. Variation	Single Outside Diameter Deviation		Single Outside Dia. Variation	Mean Outside Dia. Variation							Single Flange Outside Diameter Deviation	Single Flange Width Deviation	Flange Width Variation	Raceway Runout With Flange Face				
D		Δ_{Dmp}		Δ_{Ds}		V_{Dp}	V_{Dmp}	Δ_{Ds}		V_{Dp}	V_{Dmp}	K_e	S_D	S_e	ΔC_s (1)		VC_s	ΔD_{fs}		ΔC_{fs}		VC_f	S_{ef}
Over	Incl.	High	Low	High	Low	Max.	Max.	High	Low	Max.	Max.	Max.	Max.	Max.	High	Low	Max.	High	Low	High	Low	Max.	Max.
0	0.70866	0	-2	0	-2	1	1	-0.4	-2.4	2	2	1.4	1.6	2	0	-9.8	1	0	-9.8	0	-19.7	1	3
0.70866	1.18110	0	-2	0	-2	1	1	-0.4	-2.4	2	2	1.6	1.6	2	0	-9.8	1	0	-9.8	0	-19.7	1	3

- NOTES:
- (1) Width deviation duplex is +0 -150 (0.0001 Inch).
For additional bearings, deviation is proportional to number of bearings.
- (2) Tolerance shown are calculated from primary metric tolerances given in Table 5.3 Part 1. Conversion has been carried out far enough to yield equivalent values.
- Applicable to Instrument Ball Bearings, Metric Design, Table 4.1 Part 2

TABLE 5.4 — Part 1
TOLERANCE CLASS 9P
METRIC DESIGN

INNER RING											Dimension in mm Tolerances in micrometres		
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation		Single Bore Dia. Variation	Mean Bore Dia. Variation	Radial Runout	Bore Runout With Ref. Side	Raceway Runout With Ref. Side	Single Width Deviation		Width Variation
d		Δ_{dmp}		Δ_{ds}		V_{dp}	V_{dmp}	K_i	S_{di}	S_i	ΔB_s (1)		VB_s
Over	Incl.	High	Low	High	Low	Max.	Max.	Max.	Max.	Max.	High	Low	Max.
0	10	0	-2.5	0	-2.5	1.5	1.5	1.5	1.5	1.5	0	-25	1.5

OUTER RING										Dimension in mm Tolerances in micrometres			
Outside Diameter		Mean Outside Diameter Deviation		Single Outside Diameter Deviation		Single Outside Dia. Variation	Mean Outside Dia. Variation	Radial Runout	O.D. Cylindrical Surface Runout With Ref. Side	Raceway Runout With Ref. Side	Single Width Deviation		Width Variation
D		Δ_{Dmp}		Δ_{Ds}		V_{Dp}	V_{Dmp}	K_e	S_D	S_e	ΔC_s (1)		VC_s
Over	Incl.	High	Low	High	Low	Max.	Max.	Max.	Max.	Max.	High	Low	Max.
0	18	0	-2.5	0	-2.5	1.5	1.5	1.5	1.5	1.5	0	-25	1.5
18	30	0	-4	0	-4	2	2	2.5	1.5	2.5	0	-25	1.5

NOTES:

(1) Width deviation of duplex pairs is +0 -400 micrometres.
For additional bearings, deviation is proportional to number of bearings.

Applicable to Instrument Ball Bearings, Inch Design, Table 4.1 Part 1.

TABLE 5.4 — Part 2
TOLERANCE CLASS 9P
METRIC DESIGN

INNER RING													
Dimension in inches Tolerances in 0.0001 inch (2)													
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation		Single Bore Dia. Variation	Mean Bore Dia. Variation	Radial Runout	Bore Runout With Ref. Side	Raceway Runout With Ref. Side	Single Width Deviation		Width Variation
d		Δ_{dmp}		Δ_{ds}		V_{dp}	V_{dmp}	K_i	S_{di}	S_i	ΔB_s (1)		VB_s
Over	Incl.	High	Low	High	Low	Max.	Max.	Max.	Max.	Max.	High	Low	Max.
0	0.39370	0	-1	0	-1	0.6	0.6	0.6	0.6	0.6	0	-9.8	0.6

OUTER RING													
Dimension in inches Tolerances in 0.0001 inch (2)													
Outside Diameter		Mean Outside Diameter Deviation		Single Outside Diameter Deviation		Single Outside Dia. Variation	Mean Outside Dia. Variation	Radial Runout	O.D. Cylindrical Surface Runout With Ref. Side	Raceway Runout With Ref. Side	Single Width Deviation		Width Variation
D		Δ_{Dmp}		Δ_{Ds}		V_{Dp}	V_{Dmp}	K_e	S_D	S_e	ΔC_s (1)		VC_s
Over	Incl.	High	Low	High	Low	Max.	Max.	Max.	Max.	Max.	High	Low	Max.
0	0.70866	0	-1	0	-1	0.6	0.6	0.6	0.6	0.6	0	-9.8	0.6
0.70866	1.18110	0	-1.6	0	-1.6	0.8	0.8	1	0.6	1	0	-9.8	0.6

NOTES:

(1) Width deviation of duplex pairs is +0 -150 (0.0001 inch).
For additional bearings, deviation is proportional to number of bearings.

(2) Tolerances shown are calculated from primary metric tolerances given in Table 5.4 Part 1. Conversion has been carried out far enough to yield equivalent values.

Applicable to Instrument Ball Bearings, Metric Design, Table 4.1 Part 2.

TABLE 5.5 — Part 1
TOLERANCE CLASS 5T
METRIC DESIGN

INNER RING								Dimensions in mm Tolerances in micrometres			
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation				Radial Runout	Bore Runout With Ref. Side	Raceway Runout With Ref. Side	Width Variation
				Extra Thin Series (Table 4.2)		Thin Series (Table 4.3)					
d		Δ_{dmp}		Δ_{ds}		Δ_{ds}		K_i	S_{di}	S_i	VB_s
Over	Incl.	High	Low	High	Low	High	Low	Max.	Max.	Max.	Max.
9	18	0	-5	+2.5	-7.5	+2.5	-7.5	5	7.5	7.5	5
18	30	0	-5	+5	-10	+2.5	-7.5	5	7.5	7.5	5
30	45	0	-7.5	+7.5	-15	+2.5	-10	7.5	7.5	7.5	5
45	65	0	-10	+10	-20	+2.5	-12.5	10	7.5	10	7.5
65	80	0	-10	+15	-25	+5	-15	10	7.5	10	7.5

OUTER RING												Dimensions in mm Tolerances in micrometres			
Outside Diameter		Mean Outside Diameter Deviation		OPEN BEARINGS				SHIELDED BEARINGS				Radial Runout	O.D. Cylindrical Surface Runout With Ref. Side	Raceway Runout With Ref. Side	Width Variation
				Single Outside Diameter Deviation				Single Outside Diameter Deviation							
				Extra Thin Series (Table 4.2)		Thin Series (Table 4.3)		Extra Thin Series (Table 4.2)		Thin Series (Table 4.3)					
D		Δ_{Dmp}		Δ_{Ds}		Δ_{Ds}		Δ_{Ds}		Δ_{Ds}		K_e	S_D	S_e	VC_s
Over	Incl.	High	Low	High	Low	High	Low	High	Low	High	Low	Max.	Max.	Max.	Max.
14	28	0	-5	+2.5	-7.5	+2.5	-7.5	+5	-10	+5	-10	5	7.5	7.5	5
28	50	0	-10	+7.5	-19	+2.5	-12.5	+10	-20	+5	-15	7.5	7.5	7.5	5
50	80	0	-10	+10	-20	+2.5	-12.5	+12.5	-23	+5	-15	7.5	7.5	10	5
80	120	0	-12.5	+15	-28	+5	-18	+18	-30	+7.5	-20	10	7.5	12.5	7.5

WIDTH TOLERANCE				Dimensions in mm Tolerances in micrometres (2)	
Bore Inner Ring		Single Ring Width Deviation Inner & Outer Rings			
d		Δ_{Bs} & Δ_{Cs} (1)			
Over	Incl.	High		Low	
0	30	0		- 25	
30	80	0		-125	

NOTES:
(1) Width deviation of duplex pairs is +0 -400 micrometres for bore size up to 30 mm and +0 -500 micrometres for larger bearings. For additional bearings, deviation is proportional to number of bearings.
Applicable to Extra Thin & Thin Series Bearings, Metric Design, Tables 4.2 & 4.3, Part 1.

TABLE 5.5 — Part 2
TOLERANCE CLASS 5T
METRIC DESIGN

INNER RING								Dimensions in inches Tolerances in 0.0001 inch (2)			
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation				Radial Runout	Bore Runout With Ref. Side	Raceway Runout With Ref. Side	Width Variation
				Extra Thin Series (Table 4.2)		Thin Series (Table 4.3)					
d		Δ _{dmp}		Δ _{ds}		Δ _{ds}		K _i	S _{di}	S _i	VB _s
Over	Incl.	High	Low	High	Low	High	Low	Max.	Max.	Max.	Max.
0.35433	0.70866	0	-2	+1	-3	+1	-3	2	3	3	2
0.70866	1.18110	0	-2	+2	-3.9	+1	-3	2	3	3	2
1.18110	1.77165	0	-3	+3	-5.9	+1	-3.9	3	3	3	2
1.77165	2.55906	0	-3.9	+3.9	-7.9	+1	-4.9	3.9	3	3.9	3
2.55906	3.14961	0	-3.9	+5.9	-9.8	+2	-5.9	3.9	3	3.9	3

OUTER RING

Dimensions in inches
Tolerances in 0.0001 inch (2)

Outside Diameter		Mean Outside Diameter Deviation		OPEN BEARINGS				SHIELDED BEARINGS				Radial Runout	O.D. Cylindrical Surface Runout With Ref. Side	Raceway Runout With Ref. Side	Width Variation
				Single Outside Diameter Deviation				Single Outside Diameter Deviation							
				Extra Thin Series (Table 4.2)		Thin Series (Table 4.3)		Extra Thin Series (Table 4.2)		Thin Series (Table 4.3)					
D		Δ_{Dmp}		Δ_{Ds}		Δ_{Ds}		Δ_{Ds}		Δ_{Ds}		K_e	S_D	S_e	VC_s
Over	Incl.	High	Low	High	Low	High	Low	High	Low	High	Low	Max.	Max.	Max.	Max.
0.55118	1.10236	0	-2.0	+1	-3.0	+1	-3	+2	-3.9	+2	-3.9	2	3	3	2
1.10236	1.96850	0	-3.9	+3	-7.5	+1	-4.9	+3.9	-7.9	+2	-5.9	3	3	3	2
1.96850	3.14961	0	-3.9	+3.9	-7.9	+1	-4.9	+4.9	-9.1	+2	-5.9	3	3	3.9	2
3.14961	4.72441	0	-4.9	+5.9	-11.0	+2	-7.1	+7.1	-11.8	+3	-7.9	3.9	3	4.9	3

WIDTH TOLERANCE		Dimensions in inches Tolerances in 0.0001 inch (2)	
Bore Inner Ring		Single Ring Width Deviation Inner & Outer Rings	
d		Δ_{Bs} & Δ_{Cs} (1)	
Over	Incl.	High	Low
0	1.18110	0	-9.8
1.18110	3.14961	0	-49.2

- NOTES:
- (1) Width deviation of duplex pairs is +0-150 (0.0001 inch) for bore size up to 1.1811 inch and +0-200 (0.0001 inch) for larger bearings. For additional bearings, deviation is proportional to number of bearings.
- (2) Tolerances shown are calculated from primary metric tolerances given in Table 5.5 Part 1. Conversion has been carried out far enough to yield equivalent values.
- Applicable to Extra Thin & Thin Series Bearings, Metric Design, Tables 4.2 & 4.3, Part 2.

TABLE 5.6 — Part 1
TOLERANCE CLASS 7T
METRIC DESIGN

INNER RING								Dimensions in mm Tolerances in micrometres			
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation				Radial Runout	Bore Runout With Ref. Side	Raceway Runout With Ref. Side	Width Variation
				Extra Thin Series (Table 4.2)		Thin Series (Table 4.3)					
d		Δ _{dmp}		Δ _{ds}		Δ _{ds}		K _i	S _{di}	S _i	VB _s
Over	Incl.	High	Low	High	Low	High	Low	Max.	Max.	Max.	Max.
9	18	0	-5	0	-5	0	-5	2.5	2.5	2.5	2.5
18	30	0	-5	+2.5	-7.5	+1.5	-6.5	4	4	4	2.5
30	45	0	-5	+5	-10	+2.5	-7.5	4	4	4	2.5
45	65	0	-7.5	+7.5	-15	+2.5	-10	5	5	5	4
65	80	0	-7.5	+11.5	-19	+4	-11.5	5	5	5	4

OUTER RING												Dimensions in mm Tolerances in micrometres			
Outside Diameter		Mean Outside Diameter Deviation		OPEN BEARINGS				SHIELDED BEARINGS				Radial Runout	O.D. Cylindrical Surface Runout With Ref. Side	Raceway Runout With Ref. Side	Width Variation
				Single Outside Diameter Deviation				Single Outside Diameter Deviation							
				Extra Thin Series (Table 4.2)		Thin Series (Table 4.3)		Extra Thin Series (Table 4.2)		Thin Series (Table 4.3)					
D		Δ_{Dmp}		Δ_{Ds}		Δ_{Ds}		Δ_{Ds}		Δ_{Ds}		K_e	S_D	S_e	VC_s
Over	Incl.	High	Low	High	Low	High	Low	High	Low	High	Low	Max.	Max.	Max.	Max.
14	28	0	-5	0	-5	0	-5	+2.5	-7.5	+2.5	-7.5	4	4	5	2.5
28	50	0	-5	+5	-10	+2.5	-7.5	+7.5	-12.5	+5	-10	5	4	5	2.5
50	80	0	-7.5	+7.5	-15	+2.5	-10	+10	-18	+5	-12.5	5	4	7.5	4
80	120	0	-10	+10	-20	+2.5	12.5	+12.5	-23	+5	-15	7.5	5	7.5	5

WIDTH TOLERANCE		Dimensions in mm Tolerances in micrometres	
Bore Inner Ring		Single Ring Width Deviation Inner & Outer Rings	
d		Δ_{Bs} & Δ_{Cs} (1)	
Over	Incl.	High	Low
0	80	0	- 25

NOTES:

(1) Width deviation of duplex pairs is +0 -400 micrometres for bore size up to 30 mm and +0 -500 micrometres for larger bearings. For additional bearings, deviation is proportional to number of bearings.

Applicable to Extra Thin & Thin Series Bearings, Metric Design, Tables 4.2 & 4.3, Part 1.

TABLE 5.6 — Part 2
TOLERANCE CLASS 7T
METRIC DESIGN

INNER RING								Dimensions in inches Tolerances in 0.0001 inch (2)			
Bore Diameter		Mean Bore Diameter Deviation		Single Bore Diameter Deviation				Radial Runout	Bore Runout With Ref. Side	Raceway Runout With Ref. Side	Width Variation
				Extra Thin Series (Table 4.2)		Thin Series (Table 4.3)					
d		Δ _{dmp}		Δ _{ds}		Δ _{ds}		K _i	S _{di}	S _i	VB _s
Over	Incl.	High	Low	High	Low	High	Low	Max.	Max.	Max.	Max.
0.35433	0.70866	0	-2	0	-2	0	-2	1	1	1	1
0.70866	1.18110	0	-2	+1	-3	+0.6	-2.6	1.6	1.6	1.6	1
1.18110	1.77165	0	-2	+2	-3.9	+1	-3	1.6	1.6	1.6	1
1.77165	2.55906	0	-3	+3	-5.9	+1	-3.9	2	2	2	1.6
2.55906	3.14961	0	-3	+4.5	-7.5	+1.6	-4.5	2	2	2	1.6

OUTER RING

Outside Diameter

Mean Outside Diameter Deviation

OPEN BEARINGS

Single Outside Diameter Deviation

Extra Thin Series (Table 4.2)

Thin Series (Table 4.3)

SHIELDED BEARINGS

Single Outside Diameter Deviation

Extra Thin Series (Table 4.2)

Thin Series (Table 4.3)

Radial Runout

O.D. Cylindrical Surface Runout With Ref. Side

Raceway Runout With Ref. Side

Width Variation

D

Δ_{Dmp}

Δ_{Ds}

Δ_{Ds}

Δ_{Ds}

Δ_{Ds}

K_e

S_D

S_e

VC_s

Over

Incl.

High

Low

High

Low

High

Low

High

Low

High

Low

Max.

Max.

Max.

Max.

0.55118

1.10236

0

-2

0

-2

0

-2

+1

-3

+1

-3

1.6

1.6

2

1

1.10236

1.96850

0

-2

+2

-3.9

+1

-3

+3

-4.9

+2

-3.9

2

1.6

2

1

1.96850

3.14961

0

-3

+3

-5.9

+1

-3.9

+3.9

-7.1

+2

-4.9

2

1.6

3

1.6

3.14961

4.72441

0

-3.9

+3.9

-7.9

+1

-4.9

+4.9

-9.1

+2

-5.9

3

2

3

2

Dimensions in inches

Tolerances in 0.0001 inch (2)

WIDTH TOLERANCE		Dimensions in inches Tolerances in 0.0001 inch (2)	
Bore Inner Ring		Single Ring Width Deviation Inner & Outer Rings	
d		Δ_{Bs} & Δ_{Cs} (1)	
Over	Incl.	High	Low
0	3.14961	0	-9.8

- NOTES:
- (1) Width deviation of duplex pairs is +0 -150 (0.0001 inch) for bore size up to 1.1811 inch and +0 -200 (0.0001 inch) for larger bearings. For additional bearings, deviation is proportional to number of bearings.
- (2) Tolerances shown are calculated from primary metric tolerances given in Table 5.6 Part 1. Conversion has been carried out far enough to yield equivalent values.
- Applicable to Extra Thin & Thin Series Bearings, Metric Design, Tables 4.2 & 4.3, Part 2.

6. RADIAL INTERNAL CLEARANCE

6.1 Standard values for radial internal clearance (radial play) for bearings shown in Tables 4.1 through 4.3 are as specified in 6.2 when measured in accordance with 8.6.

6.2 Standard ranges of radial internal clearance, are as follows:

**TABLE 6.1 — Part 1
RADIAL INTERNAL CLEARANCE
METRIC Dimensions**

	Clearance In Micrometres
For Bearings in TABLE 4.1 Part 1	
Tight clearance	2-7
Normal clearance	5-12
Loose clearance	12-20
Extra-Loose clearance	20-28
For Bearings in TABLE 4.2 Part 1	
Normal clearance	8-20
Loose clearance	12-25
For Bearings in TABLE 4.3 Part 1	
With Bore Diameter	
64 mm and under	
Normal clearance	12-28
Loose clearance	20-35
Over 64mm	
Normal clearance	18-38
Loose clearance	30-50

**TABLE 6.1 — Part 2
RADIAL INTERNAL CLEARANCE
INCH Dimensions**

	Clearance In 0.0001 Inches
For Bearings in TABLE 4.1 Part 2	
Tight clearance	1-3
Normal clearance	2-5
Loose clearance	5-8
Extra-Loose clearance	8-11
For Bearings in TABLE 4.2 Part 2	
Normal clearance	3-8
Loose clearance	5-10
For Bearings in TABLE 4.3 Part 2	
With Bore Diameter	
2.5 inches and under	
Normal clearance	5-11
Loose clearance	8-14
Over 2.5 inches	
Normal clearance	7-15
Loose clearance	12-20

6.3 Clearance less than normal for thin section bearings in Tables 4.2 through 4.3 may cause excessive internal friction due to the effect of out-of-round and should be specified with caution. Less than normal values are considered non-standard and should only be established through consultation between supplier and user.

6.4 All instrument ball bearings are subject to a high percentage of internal clearance reduction as a result of tight housing or shaft fits. Residual clearance after mounting and at the operating temperature extremes is an important design consideration in selecting the proper radial play range.

7. CLASSIFICATION OF BORE AND OUTSIDE DIAMETER

When required for selective assembly or for other reasons, bores and/or outside diameters may be classified into coded size groupings within the tolerance ranges indicated in Section 5, subject to the following:

7.1 It is recognized that measurement differences between supplier and consumer can occur due to lack of gage correlation; hence, these classifications are to be considered as guides for selective assembly and not absolute size segregations.

7.2 It is understood that unless special arrangement is made between supplier and consumer, random and not specific quantities in each coded size grouping will be furnished by the supplier.

7.3 Gaging practice is to be in accordance with Paragraph 8 of this standard.

7.4 The outside diameter size for classification purposes on sealed or shielded bearings applies after seal or shield insertion.

7.5 Size classification basis for bearings listed in Tables 4.1.

7.5.1 Bore size for classification purposes is the smallest single diameter measured within the tolerance limits shown in Tables 5.1 through 5.4.

7.5.2 Outside diameter size for classification purposes is the largest single diameter measured within the tolerance limits shown in Tables 5.1 through 5.4.

7.5.3 When a shielded or sealed bearing Δ_{Ds} is found to be in excess of D_{mp} (high), is to be coded in the largest classification subject to the following limitations:

7.5.3.1 For bearings coded in increments of 2.5 μm (.0001 in.), a Δ_{Ds} (high) of + 1.0 μm (0.000040 in.) is permitted in Code 1.

7.5.3.2 For bearings coded in increments of 1.25 μm (0.000 050 in.), a Δ_{Ds} (high) of +0.5 μm (0.000 020 in.) is permitted in Code A.

7.5.4 Complete code designation consists of the bore code as the first digit or letter and the outside diameter code as the second digit or letter. When one dimension only is classified, the other is denoted by 0.

7.5.5 Classification codes are shown in Table 7.1.

TABLE 7.1 — Part 1
 CLASSIFICATION OF BORE AND OUTSIDE DIAMETERS
 2.5 MICROMETRE AND 1.25 MICROMETRE INCREMENTS

Size Range Δ_{dS} & Δ_{DS}		Code
Over	Incl.	
0.00	-2.5	1
-2.5	-5.0	2

Size Range Δ_{dS} & Δ_{DS}		Code
Over	Incl.	
0.00	-1.25	A
-1.25	-2.50	B
-2.50	-3.75	C
-3.75	-5.00	D

TABLE 7.1 — Part 2
 CLASSIFICATION OF BORE AND OUTSIDE DIAMETERS
 0.0001 INCH AND 0.000 050 INCH INCREMENTS

Size Range Δ_{dS} & Δ_{DS}		Code
Over	Incl.	
0.0000	-0.0001	1
-0.0001	-0.0002	2

Size Range Δ_{dS} & Δ_{DS}		Code
Over	Incl.	
0.000 00	-0.000 05	A
- 0.000 05	-0.000 10	B
- 0.000 10	-0.000 15	C
- 0.000 15	-0.000 20	D

EXAMPLES

Code	Description	Size Range — Micrometres
12	Bore falls between Outside diameter falls between	0.00 and -2.50 -2.50 and -5.00
2B	Bore falls between Outside diameter falls between	-2.50 and -5.00 -1.25 and -2.50
DC	Bore falls between Outside diameter falls between	-3.75 and -5.00 -2.50 and -3.75
10	Bore falls between Outside diameter is not coded	-0.00 and -2.50

7.6 Size classification basis for bearings listed in Tables 4.2 through 4.3.

7.6.1 Bore size for classification purposes is the single plane mean bore diameter (d_{mp}), measured at the middle of the ring width, within the bore tolerance limits as shown in Tables 5.5 through 5.6.

7.6.2 Outside diameter size for classification purposes is the single plane mean outside diameter (D_{mp}) measured at the middle of the ring width, within the outside diameter tolerance limits as shown in Tables 5.5 through 5.6.

7.6.3 Preferred Classification Code (Two Increment System) — Complete code designation consists of a single letter bore code followed by a single letter outside diameter code. When one dimension only is classified, the other is denoted by 0. The diameter tolerance ranges d_{mp} and D_{mp} , shall be divided into two equal groups using code letter H for the high half of the tolerance range and the code letter L for the low half of the tolerance range.

Example: For a bearing having a bore tolerance (d_{mp}) of 0.0000 to -0.0003 inch and an outside diameter tolerance (D_{mp}) of 0.0000 to -0.0004 inch, code LH designates that the mean bore diameter is within -0.00015 and -0.0003 inch and that the mean outside diameter size is within 0.0000 and - .0002 inch.

7.6.4 Alternative Classification Code (Multiple Increment System .0001 inch and 0.00005 inch increments) — Complete code designation consists of the bore code as the first digit or letter and the outside diameter code as the second digit or letter. When one dimension only is classified, the other is denoted by 0. Codings are shown in Table 7.2.

TABLE 7.2 — Part 1
CLASSIFICATION OF BORE AND OUTSIDE DIAMETERS
2.5 MICROMETRE AND 1.25 MICROMETRE INCREMENTS

Size Range Δd_{mp} & ΔD_{mp}		Code
Over	Incl.	
0.00	-2.5	1
-2.5	-5.0	2
-5.0	-7.5	3
-7.5	-10.0	4
-10.0	-12.5	5

Size Range Δd_{mp} & ΔD_{mp}		Code
Over	Incl.	
0.00	-1.25	A
-1.25	-2.50	B
-2.50	-3.75	C
-3.75	-5.00	D
-5.00	-6.25	E
-6.25	-7.50	F
-7.50	-8.75	G
-8.75	-10.00	H
-10.00	-11.25	I
-11.25	-12.50	J

TABLE 7.2 — Part 2
CLASSIFICATION OF BORE AND OUTSIDE DIAMETERS
0.0001 INCH AND 0.000 050 INCREMENTS

Size Range Δd_{mp} & ΔD_{mp}		Code
Over	Incl.	
0.000	-0.0001	1
-0.0001	-0.0002	2
-0.0002	-0.0003	3
-0.0003	-0.0004	4
-0.0004	-0.0005	5

Size Range Δd_{mp} & ΔD_{mp}		Code
Over	Incl.	
0.000 00	-0.000 05	A
-0.000 05	-0.000 10	B
-0.000 10	-0.000 15	C
-0.000 15	-0.000 20	D
-0.000 20	-0.000 25	E
-0.000 25	-0.000 30	F
-0.000 30	-0.000 35	G
-0.000 35	-0.000 40	H
-0.000 40	-0.000 45	I
-0.000 45	-0.000 50	J

8. GAGING PRACTICES

8.1 Introduction

8.1.1 Recommended practices for gaging instrument ball bearings are given in this standard for use by bearing consumers for determining acceptability.

8.1.2 Certain instrument ball bearings have extremely thin radial ring sections that can readily be deformed by gaging loads. Gaging practices and loads are therefore established to ensure agreement in measurement. However, the measuring and gaging methods may not always fully check the indicated requirements. Whether or not such methods are sufficient and acceptable depends on the magnitude of the actual deviations from the ideal dimension or form and the inspection circumstances. Bearing manufacturers frequently use specially designed measuring equipment for individual components, as well as assemblies, to increase speed and accuracy of measurement. Should the dimensional or geometrical errors appear to exceed those in the relevant specifications, when using equipment as indicated in any of the methods in this standard, the matter shall be referred to the bearing manufacturer.

8.1.3 The standards used for checking gaging equipment conform with those used by the National Institute of Standards & Technology, at a temperature of 20°C (68°F).

8.1.4 All measurements shall be made after the gaging equipment and parts to be measured have been brought to the temperature of the room in which the measurements are to be made. Care must be used to avoid heat transfer to the ring or assembled bearing being measured.

8.1.5 When gaging bearings, gage loads and dimensions of gage points are to be as shown in 8.3.

8.2 Definitions

8.2.1 Reference Side. The term “reference side” in this standard is understood to be the side of the ring so designated by the manufacturer of the bearing. On flanged outer rings the reference side is the flange back face (locating face).

8.2.2 Indicator. The term “indicator” in the methods of measuring means a calibrated and appropriately sensitive indicator.

8.3 Gage Loads and Gage Point Radii

8.3.1 A maximum gage point radius of 0.8 mm (0.032 inch) is specified for all mechanical gage measurements made on inner and outer rings of instrument ball bearings. The same gage point radius is to be used when setting the gage with master blocks and when performing measurements on bearing parts.

8.3.2 A maximum gage load of 0.6 newtons (2 ounces) is specified for all mechanical gage measurements of instrument bearings. The gaging load can be greater than 0.6 newtons provided that the gage point contact stress which is induced in the bearing is negligible and provided that the bearing ring deflection under the gaging load is less than 10 percent of the applicable tolerance. The user is strongly advised to obtain specific correlation with each bearing supplier when using a gage load greater than 0.6 newtons. Ring deflection correction factors must be considered on bearings of light section, even under light gaging loads.

8.3.3 The recommended gaging practice for instrument ball bearings is through the use of 2 point air gages, using the smallest orifices commensurate with spindle size or through the use of 2 point mechanical gaging, whichever can give the better precision accuracy for the dimension being measured. This recommendation is particularly important on inner ring bore and outer ring outside diameters for which minimum bore and maximum outside diameter measurements are necessary to accommodate assembly clearance requirements.

8.4 Inner Ring

8.4.1 Bore (d). For determining bore diameter use apparatus arranged for 2 point measurement as shown in Figure 1 . If out-of-roundness and/or taper exist in a particular bearing a reading of V_{dp} and V_{dmp} may be obtained.

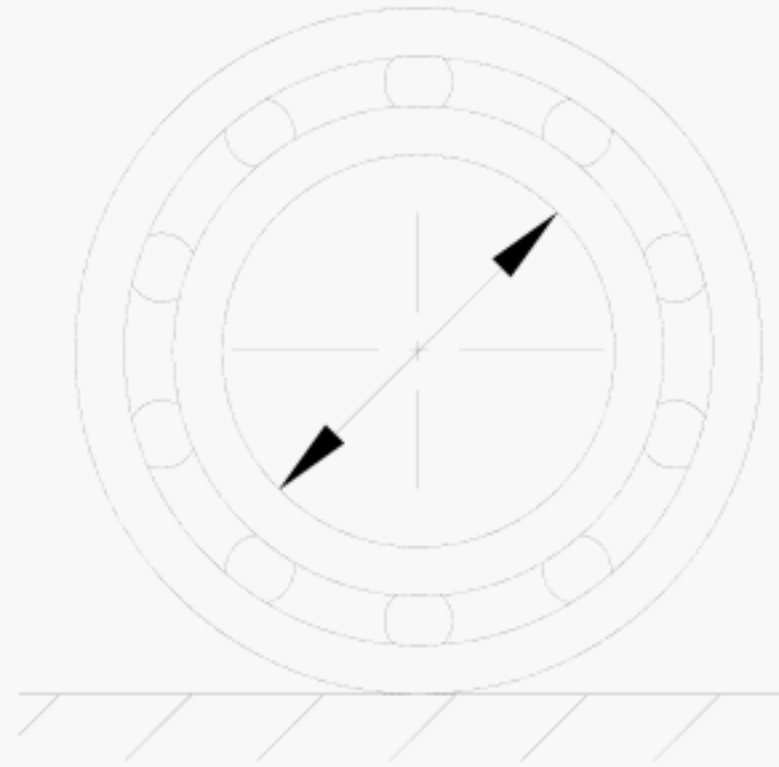


FIGURE 1

8.4.1.1 If the size or section of the bearing inner ring is such that, with the bearing axis in a horizontal position, the bore measurement is influenced by gravity by more than 10 percent of the bore tolerance, the bearing is placed with the axis in a vertical position for bore measurement.

8.4.1.2 Bore Out-of-Round (V_{dp}). The bore out-of-round of an individual ring is the maximum value of the difference between the largest and smallest actual diameters measured in a single radial plane.

8.4.1.3 Bore Taper (V_{dmp}). The bore taper of an individual ring is the greatest difference between any of three values for the single plane mean bore diameter (dmp) measured at each end of the bore surface (with the gage contacts as close to the bearing face as is practical without introducing error caused by the inner ring bore corner) and a third value of taken approximately at the center of the inner ring bore diameter.

8.4.2 Width (B). The outer ring is free and the inner ring that is to be measured is supported on one side by a suitable serrated flat anvil of such dimension as to fully support the inner ring face. Apply the indicator against the other side of the inner ring and take readings while rotating the inner ring one complete revolution. (See Figure 2A.)

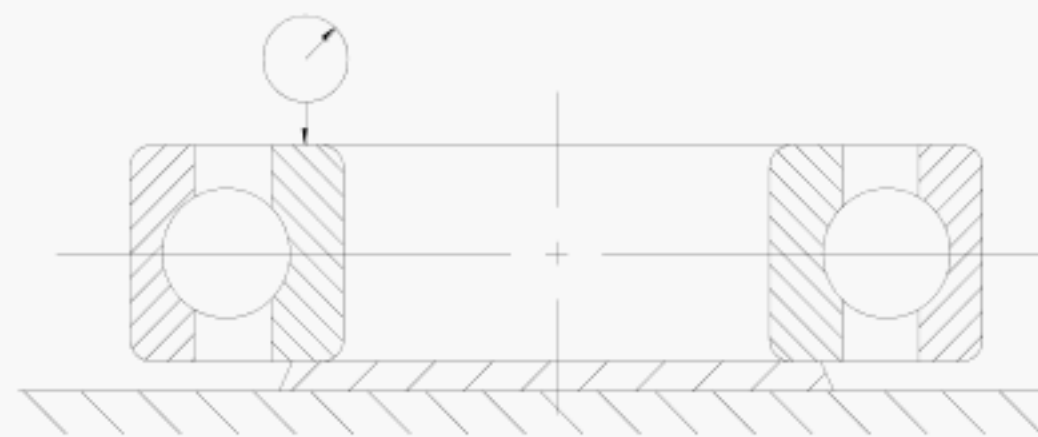


FIGURE 2A

8.4.2.1 Width (Alternate method for large, thin section, rings.) Support one side of the inner ring on three buttons, leaving the outer ring free. Apply an indicator against the other side of the inner ring directly opposite one button. Take indicator readings while rotating the inner ring one revolution. (See Figure 2B.)

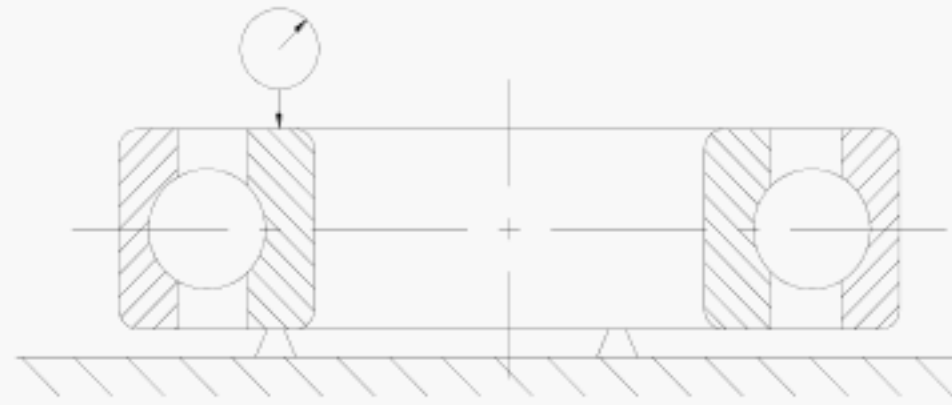


FIGURE 2B

8.4.3 Width Variation (V_{Bs}). The width variation of an individual ring is the difference between the largest and smallest widths. For measuring use the same method as applied to measurement of width.

8.4.4 Radial Runout (K_i). The size range, ring sections, tolerances and clearances of instrument ball bearings make it impracticable to check the radial runout of the inner rings of these bearings with the necessary degrees of accuracy in the assembled condition. Complex, expensive gaging is used by all bearing manufacturers to control this important ring tolerance by suitable measurements made on the individual bearing rings.

8.4.4.1 One suitable method of measuring radial runout of a bearing ring is illustrated in Figure 3. A principle of the measurement is to measure wall thickness variation between the raceway surface and the inner ring bore. The ring to be measured is placed on a suitable flat anvil with appropriate positioning blocks or stops with a coplaner gage point in radial relationship to one stop and at the bottom of the raceway. The difference between the readings on the indicator produced when the ring is slowly moved through one complete revolution can be taken as the radial runout of the part.



FIGURE 3

8.4.4.2 Where a less precise approximation of radial runout is acceptable and where the radial internal clearance (radial play) is less than $5\text{ }\mu\text{m}$ (0.0002 inch) the bearing may be mounted on a suitable arbor having a taper of 0.0001 mm per mm . An indicator with contact load not exceeding 2.2 newtons (8 ounces) and with the contact point located on the outside diameter in the plane of the raceway will provide an approximation of radial runout of the inner ring of the bearing when the arbor is rotated one revolution with the outer ring held stationary. (See Figure 4.)

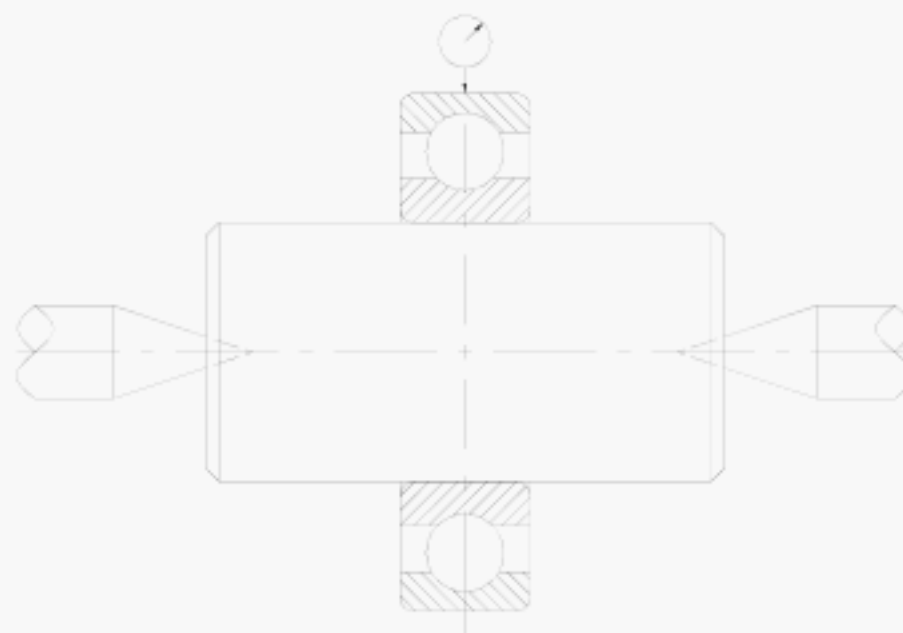


FIGURE 4
Less Precise Alternate Method

8.4.5 Raceway Runout with Reference Side (S_i). Consultation with individual bearing suppliers is suggested for bearing users who wish to institute programs of correlation on raceway runout with reference side measurements. Many unique and proprietary devices of varying design have been developed to measure raceway runout with reference side on instrument ball bearing parts.

8.4.6 Bore Runout with Reference Side (S_{d1}). Mount the inner ring with its reference side in contact with a serrated flat anvil and located by two stops oriented 90 degrees to each other and positioned in the bearing bore to be in contact with the bore as close to the surface of the anvil as is practical without entering the inner ring bore corner. Mount an indicator with a maximum contact load of 0.6 newtons (2 ounces) directly over one of the stops. The gage point should contact the inner ring bore in proximity to the upper face of the inner ring as close to the face as practicable without entering the inner ring bore corner. (see Figure 5) The bore runout with reference side is the difference between maximum and minimum indicator readings while rotating the inner ring one revolution.

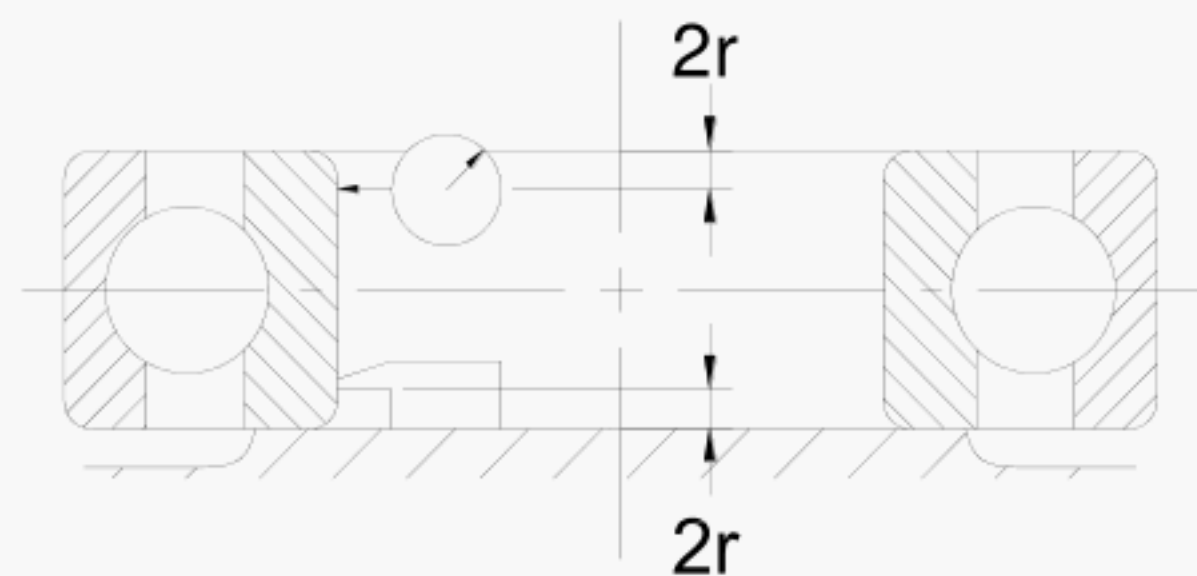


FIGURE 5

8.5 Outer Ring

8.5.1 Outside Diameter (D). For determining outside diameter use apparatus arranged for 2 point measurement as shown in Figure 6. If out-of-roundness and/or taper exist in a particular bearing, a reading of V_{Dp} and V_{Dmp} may be obtained. If the size or section of the bearing outer ring is such that, with the bearing axis in a horizontal position the outside diameter measurement is influenced by gravity by more than 10 percent of the outside diameter tolerance, the bearing is placed with the axis in a vertical position. Outside diameter measurements on flanged bearings are sometimes facilitated by placing the axis of a bearing in a vertical position.

8.5.1.1 Outside Diameter Out-of-Round (V_{Dp}). The outside diameter out-of-round of an individual ring is the maximum value of the difference between the largest and smallest actual diameters measured in a single radial plane.

8.5.1.2 Outside Diameter Taper (V_{Dmp}). The outside diameter taper of an individual ring is the greatest difference between any of three values for the single plane mean outside diameter (D_{mp}) measured at each end of the outside diameter surface (with the gage contacts as close to the bearing face as is practical without introducing error caused by the outer ring outside diameter corner) and a third value of D_{mp} , taken approximately at the center of the outer ring outside diameter.

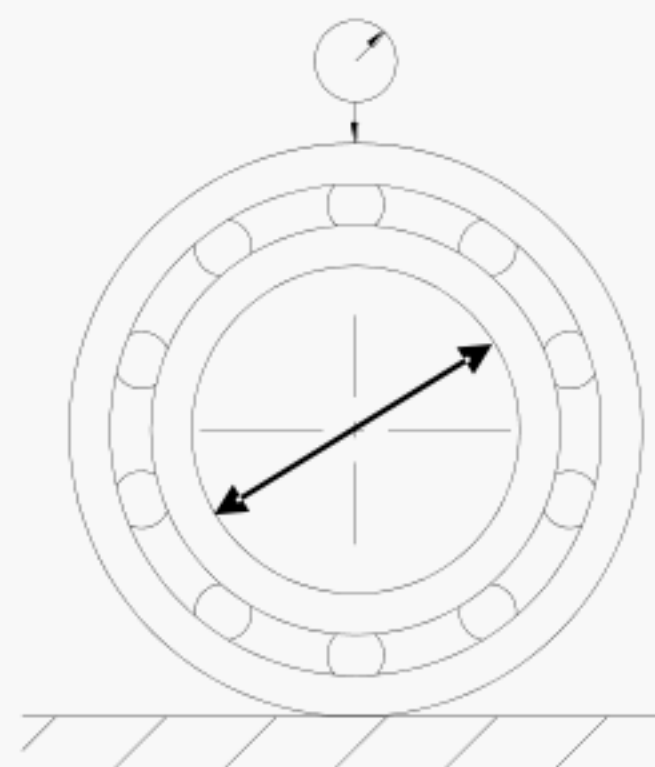


FIGURE 6

8.5.2 Width and Flange Width (C and C_1). The inner ring is free and the outer ring that is to be measured is supported on one side by a suitable serrated flat anvil of such dimension as to fully support the outer ring face. Apply the indicator against the other side of the outer ring or inside face of flange and take readings while rotating the outer ring one complete revolution. (See Figure 7A).

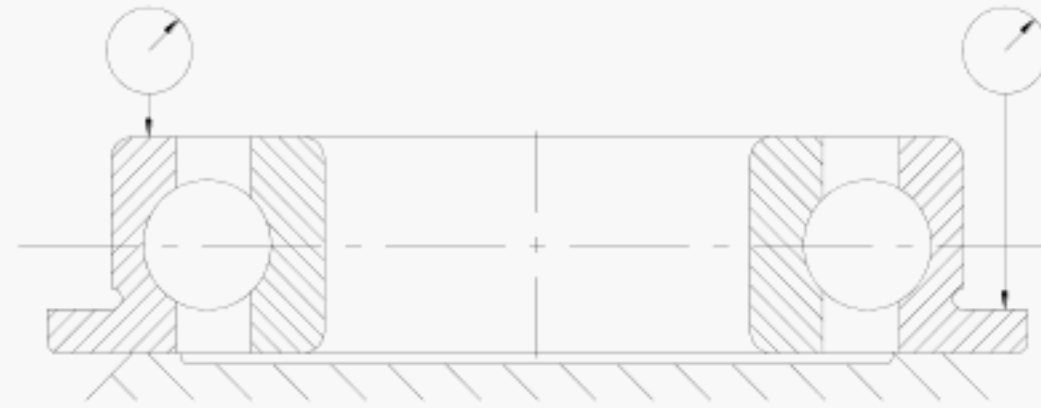


FIGURE 7A

8.5.2.1 Width and Flange Width (Alternate method for large, thin section, rings). Support one side of the outer ring on three buttons, leaving the inner ring free. Apply an indicator against the other side of the ring or inside face of flange directly opposite one button. Take indicator readings while rotating the outer ring one revolution. (See Figures 7B and 7C).

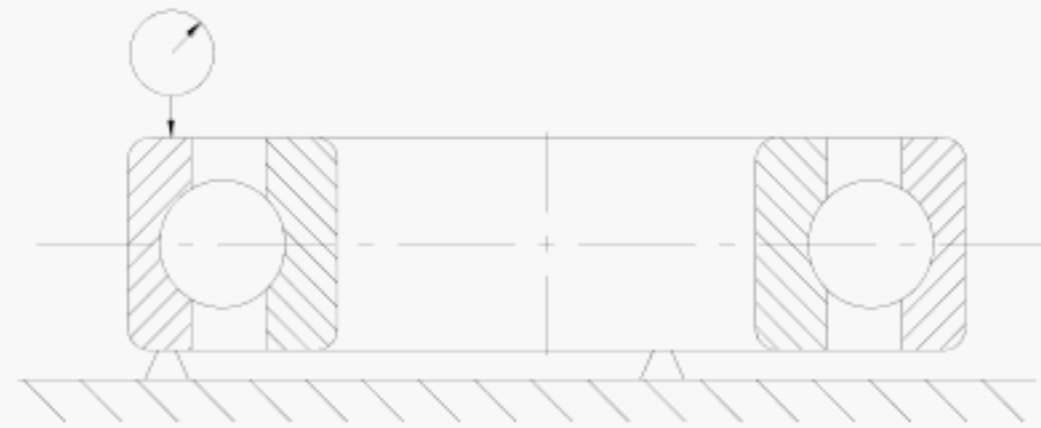


FIGURE 7B

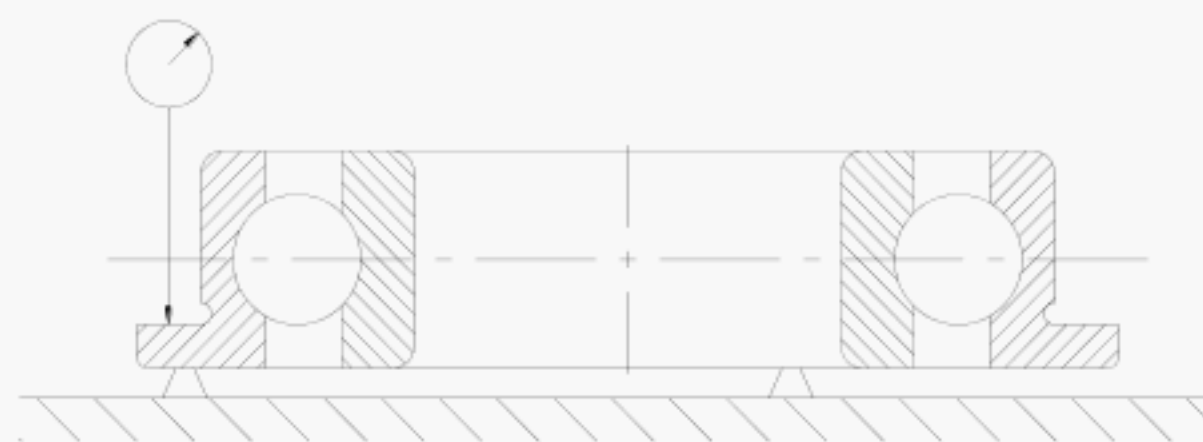


FIGURE 7C

8.5.3 Width and Flange Width Variation (VC_s , VC_{1s}). The width variation of an individual ring, or of the flange, is the difference between the largest and smallest widths. For measuring, use the same method as applied to measurement of Width.

8.5.4 Radial Runout (K_e). The size range, ring sections, tolerances and clearances of instrument ball bearings make it impractical to check the radial runout of the outer rings of these bearings with the necessary degrees of accuracy in the assembled condition. Complex, expensive gaging is used by all bearing manufacturers to control this important ring tolerance by suitable measurements made on the individual bearing rings.

8.5.4.1 One suitable method of measuring the radial runout of a bearing ring is illustrated in Figure 8. A principle of the measurement is to measure wall thickness variation between the raceway surface and the outer ring outside diameter. The ring to be measured is placed on a suitable flat anvil with appropriate positioning blocks or stops and a coplaner gage point in radial relationship to one stop and at the bottom of the raceway. The difference between the readings on the indicator produced when the ring is slowly moved through one complete revolution can be taken as the radial runout of the part.

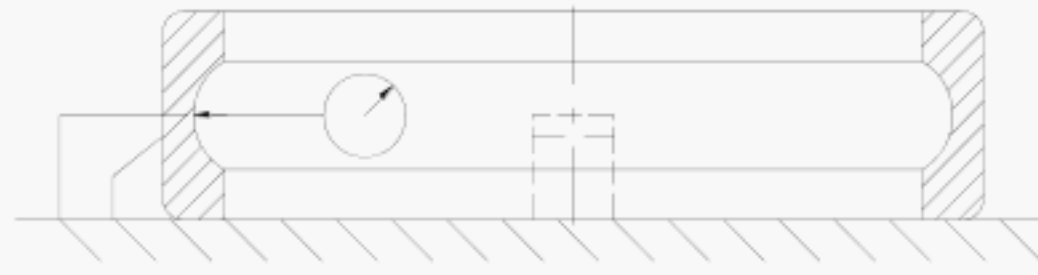


FIGURE 8

8.5.4.2 Where a less precise approximation of radial runout is acceptable and where the radial internal clearance (radial play) is less than $5\text{ }\mu\text{m}$ (0.0002 inch) the bearing may be mounted on a suitable arbor having a taper of 0.0001 mm per mm. An indicator with contact load not exceeding 2.2 newtons (8 ounces) and with the contact point located on the outside diameter in the plane of the raceway will provide an approximation of radial runout of the outer ring of the bearing when the arbor and the inner ring are held stationary, and the outer ring of the bearing is carefully turned through one complete revolution. (See Figure 9)

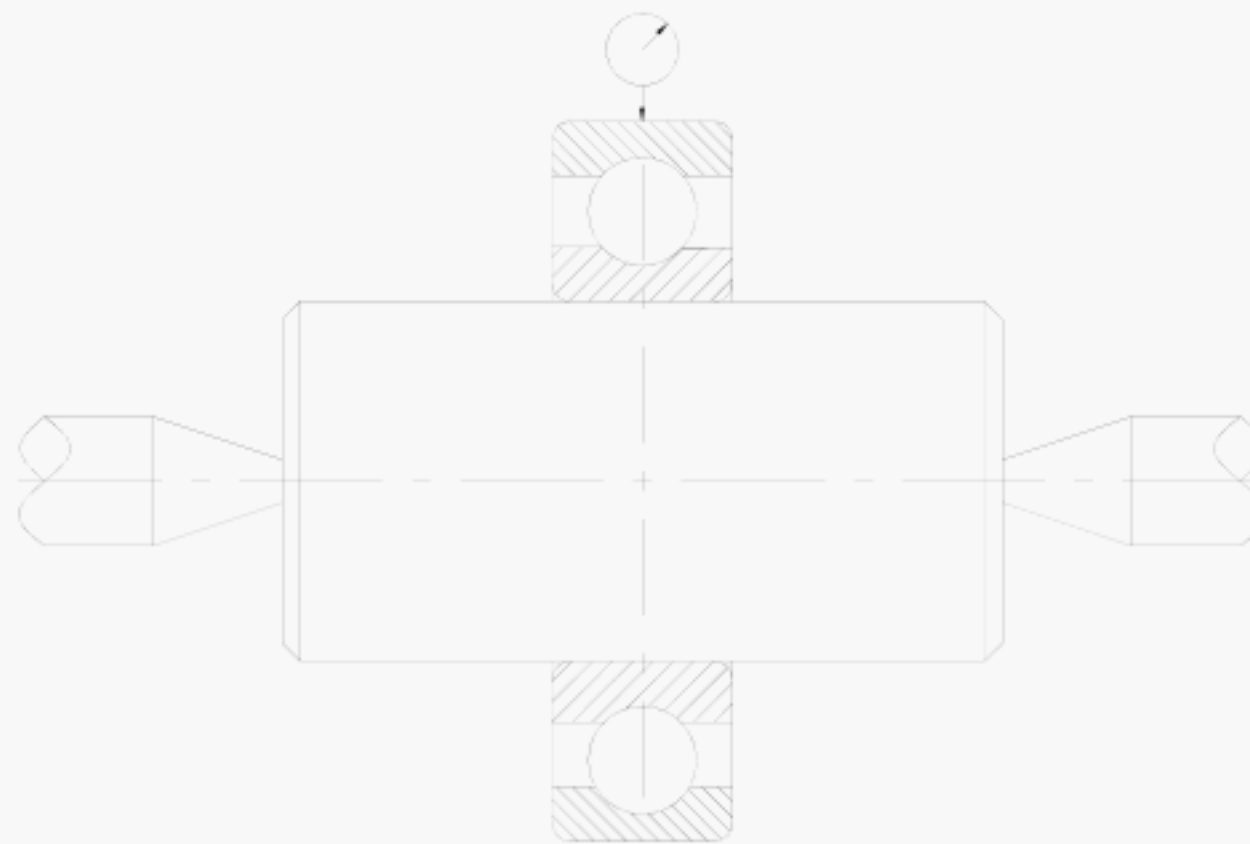


FIGURE 9
Less Precise Alternate Method

8.5.5 Raceway Runout With Reference Side (S_e , S_{e1}). Consultation with individual bearing suppliers is suggested for bearing users who wish to institute programs of correlation on raceway runout with reference side measurements. Many unique and proprietary devices of varying design have been developed to measure raceway runout with reference side on instrument ball bearing parts.

8.5.6 Outside Cylindrical Surface Runout With Reference Side (S_D). Mount the outer ring with its reference side in contact with a serrated flat anvil and located by two stops oriented 90 degrees to each other and positioned on the bearing outside diameter to be in contact with the outside diameter as close to the surface of the anvil as is practical without entering the outer ring corner. Mount an indicator with a maximum contact load of 0.6 newtons (2 ounces) directly over one of the stops. The gage point should contact the outer ring outside diameter in proximity with the upper face of the outer ring as close to the face as practicable without entering the outer ring corner. The outside cylindrical surface runout with reference side is the difference between maximum and minimum indicator readings when rotating the outer ring one revolution. (See Figure 10)



FIGURE 10

8.6 Radial Internal Clearance — (Radial Play)

8.6.1 The radial internal clearance of a single row radial or angular contact ball bearing is the average outer ring raceway diameter, minus the average inner ring raceway diameter, minus twice the ball diameter. The raceway diameter is measured at the bottom of the raceway.

8.6.2 Measured radial internal clearance is obtained by using effective gage loads, light enough to avoid excessive deflections, yet sufficient to overcome gage friction, inertia and lubricant film effects and provide repeatable readings. Some lubricants may adversely affect measured radial internal clearance. In these cases, measurements should be obtained with a film of light oil.

8.6.2.1 The average of readings taken at three different outside diameter positions, using suitable gaging equipment and corrected by referencing to a bearing having known radial internal clearance, constitutes the radial internal clearance of a particular bearing.

8.6.2.2 Since different bearing manufacturers use different radial internal clearance measuring devices which may apply different effective gage loads, the bearing user should correlate their measurements with those of the bearing supplier.

9. BALL BEARING TORQUE

9.1 Introduction

9.1.1 The resistance to rotation under an applied moment (friction torque) is a significant design consideration in instrument ball-bearing application. Application conditions such as loadings, speeds, and lubrication influence torque values as do the physical features obtained through the design and manufacture of the bearing itself. Since the variety of application conditions are infinite, standard test conditions have been devised for bearings in Table 4.1 to measure bearing torque levels independently from application consideration. These test conditions include application of a specific axial load so that all balls are in contact and the entire raceway ball path circumference is exposed to ball contact. Measured torque values may be compared with empirically derived levels as an indication of the effectiveness of bearing fabrication.

9.1.2 Since no two rolling bearings are exactly identical as to average and maximum torque values, and furthermore, since different types of testers exhibit differing degrees of extent and exaggeration of peak torque values, correlation of measurement between different types of testers has proven difficult to resolve. Specification of torque values, therefore, should be agreed upon the basis of a particular type and design of tester, unless correlation of test results on different testers between supplier and user is well established and understood.

9.2 Definitions

9.2.1 Ball Bearing Torque — Friction torque in a ball bearing is the total moment needed to rotate one raceway member of the bearing while the other member is held stationary.

9.2.2 Starting Torque — Starting torque is the applied torque necessary to start and maintain rotation of one raceway member with the other member stationary according to test conditions of paragraph 9.3.2.

9.2.3 Running Torque — Running torque is the applied torque necessary to restrain motion of one raceway member while the other raceway member is rotated according to test conditions of paragraph 9.3.3.

9.2.4 Maximum Torque — Maximum torque is the maximum value of torque recorded during any test cycle.

9.2.5 Standard Torque Unit — The standard units of torque shall be the micronewton metre.

9.2.6 Test Load — The test load is a specified axial load applied coincident with the axis of rotation of the bearing.

9.3 Test Conditions

9.3.1 General

9.3.1.1 Ambient Conditions — Testing shall be conducted in an atmosphere controlled clean environment on a relatively vibration-free base. Temperature shall be maintained within 20-24°C (68-76°F) and relative humidity below 55%.

9.3.1.2 Pre-Test Condition of Bearings — Before testing, bearings shall be de-magnetized and cleaned thoroughly with clean mineral solvent filtered through a 0.5 micron or better filter. After cleaning, bearings shall be lubricated with an adequate amount of a light instrument oil filtered through a 0.5 micron or better filter and having a viscosity not exceeding 14 cs at 38°C (100 °F). After applying the lubricant, the bearing shall be rotated slowly for a minimum of five full revolutions to distribute the lubricant.

9.3.1.3 Test Loading — Axial loads shall be as specified in Table 9. The loads shall be applied with the axis position of the bearing vertical.

9.3.1.4 Re-Test Provisions — Bearings that fail to pass the specified test cycle shall be recleaned and retested. Bearings failing the second test cycle shall again be recleaned and retested. All bearings failing the third test cycle shall be considered as failing the test. When retesting is required, all bearings in the lot being evaluated shall be subject to the recleaning operations.

9.3.2 Starting Torque

9.3.2.1 The test cycle for an individual bearing shall consist of a minimum of ten starts: Five starts each with load in each direction.

9.3.2.2 A start is obtained when the rotating raceway member starts and maintains rotation through a 60° arc.

9.3.3 Running Torque

9.3.3.1 The test cycle for an individual bearing shall consist of a 360° rotation of the rotating raceway member, followed by a 360° rotation in the opposite direction.

9.3.3.2 Rotation speed shall be between 0.5 and 2 rpm. For any given test the same rotation speed shall apply for both clockwise and counterclockwise rotation.

TABLE 9 — Part 1
TEST LOADING
AXIAL LOADS FOR BEARINGS LISTED
IN TABLE 4.1 — Part 1

Bore d	O.D. D	TEST LOAD (newtons)
1.5	4	0.75
1.5	5	0.75
2.0	5	0.75
2.0	6	0.75
2.5	6	0.75
2.5	7	0.75
3.0	7	0.75
3.0	8	0.75
3.0	10	4.00
4.0	9	0.75
4.0	11	4.00
4.0	13	4.00
4.0	16	4.00
5.0	11	4.00
5.0	13	4.00
5.0	16	4.00
5.0	19	4.00
6.0	13	4.00
6.0	15	4.00
6.0	19	4.00
7.0	14	4.00
7.0	17	4.00
7.0	19	4.00
7.0	22	4.00
8.0	16	4.00
8.0	19	4.00
8.0	22	4.00
8.0	24	4.00
9.0	17	4.00
9.0	20	4.00
9.0	24	4.00
9.0	26	4.00

TABLE 9 — Part 2
TEST LOADING
AXIAL LOADS FOR BEARINGS LISTED
IN TABLE 4.1 — Part 2

Bore (inches) d	O.D. (inches) D	TEST LOAD (newtons)
0.05906	0.15748	0.75
0.05906	0.19685	0.75
0.07874	0.19685	0.75
0.07874	0.23622	0.75
0.09843	0.23622	0.75
0.09843	0.27559	0.75
0.11811	0.27559	0.75
0.11811	0.31496	0.75
0.11811	0.39370	4.00
0.15748	0.35433	0.75
0.15748	0.43307	4.00
0.15748	0.51181	4.00
0.15748	0.62992	4.00
0.19685	0.43307	4.00
0.19685	0.51181	4.00
0.19685	0.62992	4.00
0.19685	0.74803	4.00
0.23622	0.51181	4.00
0.23622	0.59055	4.00
0.23622	0.74803	4.00
0.27559	0.55118	4.00
0.27559	0.66929	4.00
0.27559	0.74803	4.00
0.27559	0.86614	4.00
0.31496	0.62992	4.00
0.31496	0.74803	4.00
0.31496	0.86614	4.00
0.31496	0.94488	4.00
0.35433	0.66929	4.00
0.35433	0.78740	4.00
0.35433	0.94488	4.00
0.35433	1.02362	4.00

10. LIMITATIONS OF BEARING YIELD RATES

10.1 Special requirements for accurate position control of a rotating member in relation to its support may necessitate limitations of bearing yield rates. These yield rate limitations are governed by specialized control of bearing contact angles and/or preload.

10.2 Contact angle is established by the magnitude of bearing radial internal clearance, internal design and applied axial preload and largely governs the magnitudes of the axial and radial yield rates. When tolerances on contact angle are specified, normal radial internal clearance standards do not apply.

10.3 Axial preload is established by axially loading one bearing against another either by an adjustment system external to the bearings or by the use of axially preloaded duplex bearing pairs which, when the appropriate rings are clamped together, will establish the required magnitude of axial loading within the pair. In such cases, the normal tolerances that apply to the individual ring widths may be exceeded.

11. RECOMMENDED BEARING MOUNTING PRACTICE

11.1 Introduction

11.1.1 The following recommended shaft and housing fit ranges are derived from successful experience with normal instrument ball bearing applications where non-interference fits are used. Correct use of these fits necessitates compliance with specified geometric and finish limitations. Since the value of factors affecting the proper selection of fits will vary due to the range of environmental and operational conditions possible in instrument ball bearing applications, it must be recognized that certain applications will require specific fitting procedure to more closely control bearing performance. When specifying shaft and housing fits other than those recommended, certain precautions must be considered to ensure a successful application.

11.2 Recommended Fit Ranges

11.2.1 The fit ranges listed in Tables 11.1 through 11.3 are general fits which assume the shaft and housing materials to have generally the same coefficient of expansion as the bearing material. Furthermore, the finish and geometry limitations specified in Paragraph 11.3 must be held to ensure a satisfactory application.

TABLE 11.1 — Part 1
RECOMMENDED FIT RANGES FOR RANDOM ASSEMBLY OF NON-CLASSIFIED BEARINGS

Dimensions in micrometres

Ring Diameter Tolerance Limit	Shaft Diameter		Resulting Fit	Housing Diameter		Resulting Fit
Deviation from d or D	Deviation from d			Deviation from D		
	Max.	Min.		Min.	Max.	
2.5	-2.5	-5	0 to 5L	0	+ 2.5	0 to 5L
4	Not Applicable			0	+ 2.5	0 to 6.5L
5	- 5	- 10	0 to 10L	0	+ 5	0 to 10L
7.5	- 7.5	- 15	0 to 15L	0	+ 7.5	0 to 15L
10	- 10	- 20	0 to 20L	0	+ 8	0 to 20L
12.5	Not Applicable			0	+ 12.5	0 to 25L

TABLE 11.1 — Part 2
RECOMMENDED FIT RANGES FOR RANDOM ASSEMBLY OF NON-CLASSIFIED BEARINGS

Dimensions in 0.0001 inch

Ring Diameter Tolerance Limit	Shaft Diameter		Resulting Fit	Housing Diameter		Resulting Fit
Deviation from d or D	Deviation from d			Deviation from D		
	Max.	Min.		Min.	Max.	
1	-1	-2	0 to 2L	0	+ 1	0 to 2L
1.5	Not Applicable			0	+ 1	0 to 2.5L
2	- 2	- 4	0 to 4L	0	+ 2	0 to 4L
3	- 3	- 6	0 to 6L	0	+ 3	0 to 6L
4	- 4	- 8	0 to 8L	0	+ 4	0 to 8L
5	Not Applicable			0	+ 5	0 to 10L

TABLE 11.2 — Part 1
 RECOMMENDED FIT RANGES FOR SELECTIVE ASSEMBLY OF BEARINGS CLASSIFIED IN TWO INCREMENT SYSTEM*

Dimensions in micrometres							
Ring Diameter Tolerance Limit	Bore or Outside Diameter	Shaft Diameter		Resulting Fit	Housing Diameter		Resulting Fit
		Deviation from d			Deviation from D		
Deviation from d or D	Classification Code	Max.	Min.		Min.	Max.	
5	H	- 2.5	- 5	0 to 5L	0	+ 2.5	0 to 5L
	L	- 5	-7.5		- 2.5	+ 0	
7.5	H	- 4	-7.5	0 to 7.5L	0	+ 4	0 to 7.5L
	L	- 7.5	-11.5		- 4	0	
10	H	- 5	- 10	0 to 10L	0	+ 5	0 to 10L
	L	- 10	- 20		- 5	0	
12.5	H	Not Applicable			0	+ 6.5	0 to 12.5L
	L				- 6.5	+ 0	

TABLE 11.2 — Part 2
 RECOMMENDED FIT RANGES FOR SELECTIVE ASSEMBLY OF BEARINGS CLASSIFIED IN TWO INCREMENT SYSTEM*

Dimensions in 0.0001 inch

Ring Diameter Tolerance Limit	Bore or Outside Diameter	Shaft Diameter		Resulting Fit	Housing Diameter		Resulting Fit
		Deviation from d			Deviation from D		
Deviation from d or D	Classification Code	Max.	Min.		Min.	Max.	
2	H	- 1	- 2	0 to 2L	0	+ 1	0 to 2L
	L	- 2	- 3		- 1	+ 0	
3	H	- 1.5	- 3	0 to 3L	0	+ 1.5	0 to 3L
	L	- 3	- 4.5		- 1.5	0	
4	H	- 2	- 4	0 to 4L	0	+ 2	0 to 4L
	L	- 4	- 8		- 2	0	
5	H	Not Applicable			0	+ 2.5	0 to 5L
	L				- 2.5	+ 0	

* Refer to paragraph 7.6.3.

TABLE 11.3 — Part 1
RECOMMENDED FIT RANGES FOR SELECTIVE ASSEMBLY OF BEARINGS CLASSIFIED IN 2.5 MICROMETRE INCREMENTS*

Dimensions in micrometres						
Bore or Outside Diameter	Shaft Diameter		Resulting Fit	Housing Diameter		Resulting Fit
Classification Code	Deviation from d			Deviation from D		
	Max.	Min.		Min.	Max.	
1	- 2.5	- 5	0 to 5L	0	+ 2.5	0 to 5L
2	- 5	- 7.5		- 2.5	+ 0	
3	- 7.5	- 10		- 5	- 2.5	
4	- 10	- 12.5		- 7.5	- 5	
5	Not Applicable			- 10	- 7.5	

TABLE 11.3 — Part 2
RECOMMENDED FIT RANGES FOR SELECTIVE ASSEMBLY OF BEARINGS CLASSIFIED IN 0.0001 INCH INCREMENTS*

Dimensions in 0.0001 inch

Bore or Outside Diameter	Shaft Diameter		Resulting Fit	Housing Diameter		Resulting Fit
Classification Code	Deviation from d			Deviation from D		
	Max.	Min.		Min.	Max.	
1	-1	-2	0 to 2L	0	+ 1	0 to 2L
2	- 2	- 3		- 1	+ 0	
3	- 3	- 4		- 2	- 1	
4	- 4	- 5		- 3	- 2	
5	Not Applicable			- 4	- 3	

* Refer to paragraph 7.6.3.

11.3 Geometry and Finish Requirements

11.3.1 The following values are the maximum numerical limits that should be considered relative to shaft and housing finishes and geometry when utilizing the recommended fits established in this document.

11.3.1.1 Surface roughness, shaft and housing mounting surfaces: 0.40 micrometres max. Arithmetic Average (16AA).

11.3.1.2 Out-of-Roundness. Tolerance for shaft and housing roundness shall be one-half the tolerance range, Δ_{dmp} or Δ_{Dmp} , for the ABEC tolerance class of the bearings.

11.3.1.3 Squareness. Squareness of mounting faces to shaft and housing mounting surfaces shall be equivalent to the values specified for the ABEC tolerance class of the bearing for “bore runout with reference side” S_{d1} and “outside cylindrical surface runout with reference side” S_D .

11.3.1.4 Misalignment. Limits for permissible misalignment are dependent on the bearing internal geometry and mounted internal radial clearance. Consult the individual bearing manufacturer for recommendation for the specific bearing application under consideration.

11.3.1.5 Taper of Mounting Surfaces. Tolerance for taper of shaft and housing mounting surfaces shall be one-half the tolerance range, Δ_{dmp} or Δ_{Dmp} for the ABEC tolerance class of the bearing.

11.4 Special Fitting Practice

11.4.1 Since it is impossible to standardize on fitting practices to encompass specialized applications, it is best to contact the bearing manufacturer for engineering assistance relative to the application of their product when faced with an unusual mounting situation.

11.4.2 In those cases where the environmental and operational conditions or accuracy requirements preclude the use of loose shaft and housing fits, the following precautions must be considered:

11.4.2.1 In general, it is not recommended that an individual bearing be mounted with an interference fit to both the shaft and the housing. This is particularly important in the majority of cases where relief of axial thermal expansion should be provided by allowing one bearing ring to move axially on its seating.

11.4.2.2 When an interference fit must be specified, it should normally be specified for the rotating member.

11.4.2.3 Care must be taken to ensure that any bearing that is to be interference fitted has sufficient radial internal clearance to preclude possibility of radially preloading or altering predetermined preload values when it is mounted with the specified interference. The reduction of radial internal clearance due to an interference fit is dependent upon the materials, the section thickness of the bearing ring and mounting surface, and the effect of temperature. As an approximation, 80% of the total interference is taken up by reduction of internal clearance.

11.4.2.4 Any interference fit automatically imposes closer geometric tolerances on the mating mounting surfaces if the precision built into the bearing is to be realized in the end function.

11.4.2.5 Provision should be made in the design to ensure that the interference fitted members may be assembled first to eliminate the possibility of internally damaging the bearing during assembly. Care must be taken at assembly to ensure that the force necessary to establish the interference fit is applied directly to the bearing ring and not transmitted to it through the ball complement.

11.4.2.6 Care must be taken when dissimilar metals are used for shaft and housing to ensure that excessive radial tightness or looseness is not experienced at the temperature extremes of the application. This is especially important where high speed and/or high load situations are involved.

11.5 Shaft and Housing Shoulder Diameters

11.5.1 Shoulders must be provided to properly locate bearings on shafts and in housings. Table 11.4, Part 1 and Part 2, Table 11.5, Part 1 and Part 2, and Table 11.6, Part 1 and Part 2, represent the minimum shaft shoulder diameters which will properly locate the bearings on the shafts, and the maximum housing shoulder diameters that will properly locate the bearings in the housings, when instrument ball bearings are mounted for use under radial loads or light thrust loads. Other types of loads may require higher shoulders, resulting in larger diameter shaft shoulders or smaller diameter housing shoulders, to carry their thrust loads. Deviations from the values listed below should be reviewed with the manufacturers to assure that interference with the bearing components will not result.

TABLE 11.4 — Part 1
MINIMUM SHAFT AND MAXIMUM HOUSING
SHOULDER DIAMETERS FOR METRIC
INSTRUMENT BALL BEARINGS LISTED IN
TABLE 4.1

Dimensions in mm			
Bore d	Outside Diameter D	Minimum Shaft Shoulder Diameter h _{min}	Maximum Housing Shoulder Diameter H _{max}
1.5	4.0	2.00	3.50
1.5	5.0	2.14	4.36
2.0	5.0	2.60	4.40
2.0	6.0	2.71	5.29
2.5	6.0	3.14	5.36
2.5	7.0	3.24	6.26
3.0	7.0	3.71	6.29
3.0	8.0	3.78	7.22
3.0	10.0	4.02	8.98
4.0	9.0	4.78	8.22
4.0	11.0	5.02	9.98
4.0	13.0	5.16	11.84
4.0	16.0	5.67	14.33
5.0	11.0	5.95	10.05
5.0	13.0	6.05	11.95
5.0	16.0	6.60	14.40
5.0	19.0	6.81	17.19
6.0	13.0	7.02	11.98
6.0	15.0	7.16	13.84
6.0	19.0	7.74	17.26
7.0	14.0	8.02	12.98
7.0	17.0	8.23	15.77
7.0	19.0	8.67	17.33
7.0	22.0	8.88	20.12
8.0	16.0	9.05	14.95
8.0	19.0	9.30	17.70
8.0	22.0	9.81	20.19
8.0	24.0	9.95	22.05
9.0	17.0	10.05	15.95
9.0	20.0	10.60	18.40
9.0	24.0	10.88	22.12
9.0	26.0	11.62	23.38

TABLE 11.4 — Part 2
MINIMUM SHAFT AND MAXIMUM HOUSING
SHOULDER DIAMETERS FOR METRIC
INSTRUMENT BALL BEARINGS LISTED IN
TABLE 4.1

Dimensions in inches			
Bore d	Outside Diameter D	Minimum Shaft Shoulder Diameter h _{min}	Maximum Housing Shoulder Diameter H _{max}
0.059 06	0.157 48	0.079	0.138
0.059 06	0.196 85	0.084	0.172
0.078 74	0.196 85	0.102	0.173
0.078 74	0.236 22	0.107	0.208
0.098 43	0.263 22	0.124	0.211
0.098 43	0.275 59	0.128	0.246
0.118 11	0.275 59	0.146	0.248
0.118 11	0.314 96	0.149	0.284
0.118 11	0.393 70	0.158	0.354
0.157 48	0.354 33	0.188	0.324
0.157 48	0.433 07	0.198	0.323
0.157 48	0.511 81	0.203	0.466
0.157 48	0.629 92	0.223	0.564
0.196 85	0.433 07	0.234	0.396
0.196 85	0.511 87	0.238	0.470
0.196 85	0.629 92	0.260	0.567
0.196 85	0.748 03	0.268	0.677
0.236 22	0.511 81	0.276	0.472
0.236 22	0.590 55	0.282	0.545
0.236 22	0.748 03	0.305	0.680
0.275 59	0.551 18	0.316	0.511
0.275 59	0.669 29	0.324	0.621
0.275 59	0.748 03	0.341	0.682
0.275 59	0.866 14	0.350	0.792
0.314 96	0.629 92	0.356	0.588
0.314 96	0.748 03	0.366	0.697
0.314 96	0.866 14	0.386	0.795
0.314 96	0.944 88	0.392	0.868
0.354 33	0.669 29	0.396	0.628
0.354 33	0.787 40	0.417	0.724
0.354 33	0.944 88	0.428	0.871
0.354.33	1.023 62	0.457	0.920

TABLE 11.5 — Part 1
 MINIMUM SHAFT AND MAXIMUM HOUSING
 SHOULDER DIAMETERS FOR METRIC
 INSTRUMENT BALL BEARINGS —
 EXTRA-THIN SERIES — LISTED IN TABLE
 4.2

Dimensions in mm

Bore d	Outside Diameter D	Minimum Shaft Shoulder Diameter h _{min}	Maximum Housing Shoulder Diameter H _{max}
10	15	11.40	13.60
12	18	13.40	16.60
15	21	16.40	19.60
17	23	18.40	21.60
20	27	21.40	25.60
25	32	26.40	30.60
30	37	31.40	35.60

TABLE 11.5 — Part 2
 MINIMUM SHAFT AND MAXIMUM HOUSING
 SHOULDER DIAMETERS FOR METRIC
 INSTRUMENT BALL BEARINGS —
 EXTRA-THIN SERIES — LISTED IN TABLE
 4.2

Dimensions in inches

Bore d	Outside Diameter D	Minimum Shaft Shoulder Diameter h _{min}	Maximum Housing Shoulder Diameter H _{max}
0.393 70	0.590 55	0.449	0.535
0.472 44	0.708 66	0.528	0.654
0.590 55	0.826 77	0.646	0.772
0.669 29	0.905 51	0.724	0.850
0.787 40	1.062 99	0.843	1.008
0.984 25	1.259 84	1.039	1.205
1.181 10	1.456 69	1.236	1.402

TABLE 11.6 — Part 1
 MINIMUM SHAFT AND MAXIMUM HOUSING
 SHOULDER DIAMETERS FOR METRIC
 INSTRUMENT BALL BEARINGS —
 THIN SERIES — LISTED IN TABLE 4.3

Dimensions in mm

Bore d	Outside Diameter D	Minimum Shaft Shoulder Diameter h _{min}	Maximum Housing Shoulder Diameter H _{max}
20	32	22.57	29.43
25	37	27.57	34.43
30	42	32.57	39.43
35	47	37.57	44.43
40	52	42.57	49.43
50	65	53.12	61.88
60	78	63.68	74.32
70	90	74.65	85.35
80	100	84.65	95.35

TABLE 11.6 — Part 2
 MINIMUM SHAFT AND MAXIMUM HOUSING
 SHOULDER DIAMETERS FOR METRIC
 INSTRUMENT BALL BEARINGS —
 THIN SERIES — LISTED IN TABLE 4.3

Dimensions in inches

Bore d	Outside Diameter D	Minimum Shaft Shoulder Diameter h _{min}	Maximum Housing Shoulder Diameter H _{max}
0.787 40	1.259 84	0.889	1.159
0.984 25	1.456 69	1.085	1.356
1.181 10	1.653 54	1.282	1.552
1.377 95	1.850 39	1.479	1.749
1.574 80	2.047 24	1.676	1.946
1.968 50	2.559 05	2.091	2.436
2.632 20	3.070 86	2.507	2.926
2.755 90	3.543 30	2.939	3.360
3.149 60	3.937 00	3.333	3.754

12. STATIC LOAD RATING AND BEARING LIFE

12.1 Static Load Rating

The static load rating, radial or axial, is that load (or combination of loads) which a non-rotating ball bearing will support without damage, and continue to provide satisfactory performance and life. As stated in Paragraph 2.2, performance, as reflected by end use requirements, is one of the distinguishing characteristics of instrument ball bearings.

Static load rating is dependent on the maximum contact stress between the balls and either of the two raceways. It is affected by material, hardness, number and size of balls, raceway curvatures and depths, and contact angle. It has been established that when contact stress exceeds 3.5 GPa (508 000 psi) the loads may have a significant effect on vibration level and torque uniformity for the conditions encountered and performance desired. It has also been established that bearing fatigue life is unaffected by static loads resulting in maximum contact stress as high as 4.0 GPa (580 000 psi).

12.1.1 Static Radial Load Rating — The static radial load rating is that pure radial load, which when applied to a non-rotating ball bearing, will result in a maximum stress level under the most heavily loaded ball, not greater than values given in Paragraph 12.1.

12.1.2 Static Axial Load Rating — The static axial load rating of a ball bearing is that pure axial load, which when applied to a ball bearing, will result in:

- 1) A maximum stress level not greater than levels defined in Paragraph 12.1.

and

- 2) A contact ellipse under all balls which lies completely within the raceway (i.e., the contact ellipse is not truncated by the raceway shoulder on either the inner or outer ring).

12.2 Bearing Life

The life of an individual ball bearing is the number of revolutions (or number of hours at some given constant speed) which the bearing runs before the first evidence of fatigue develops in the material of the inner ring, outer ring, or balls. The subject of bearing life is discussed in greater detail in ANSI/ABMA Standard 9.

12.2.1 Basic Dynamic Radial Load Rating

The basic dynamic radial load rating, C_r , for radial and angular contact ball bearings with balls not larger than 25.4 mm (1 inch) in diameter is:

$$C_r = f_{cm} (i \cos \alpha)^{0.7} Z^{2/3} D_w^{1.8}$$

Values of f_{cm} for commonly used design parameters are given in Table 12.2 Part 1 for newton and millimetre units and in Table 12.2 Part 2 for pound and inch units.

12.2.2 Rating Life

The rating life of a ball bearing is L_n

$$L_n = a_1 a_2 a_3 \frac{16666}{N} \left(\frac{C_r}{P_r} \right)^3 \text{ -Hours}$$

Where:

- C_r is basic load rating
- N is bearing rotational speed --- rpm
- a_1, a_2, a_3 are life adjustment factors (See Paragraph 12.2.3)
- (Also refer to ANSI/ABMA Std. 9)
- P is the equivalent radial load.
- For a pure radial load $F_r - P = F_r$
- For a pure thrust load $F_a - P = Y F_a$
- For combined loads P is the larger of
- $P_r = F_r$

or

$$P_r = X F_r + Y F_a$$

$$X = \frac{1.25 - \sin \alpha}{2.50 - \sin \alpha} \qquad = \text{Radial Load Factor}$$

$$Y = \frac{0.4 \cot \alpha}{1 - 0.333 \sin \alpha} \qquad = \text{Axial Load Factor}$$

Values of α_t may be determined by Figure 11, or obtained from a bearing manufacturer.

12.2.3 Life Adjustment Factors

a_1 is the life adjustment factor for reliability. Values of a_1 are given in Table 12.1 below.

TABLE 12.1
LIFE ADJUSTMENT FACTOR FOR RELIABILITY

RELIABILITY		
%	L_n	a_1
90	L_{10}	1
95	L_5	0.62
96	L_4	0.53
97	L_3	0.44
98	L_2	0.33
99	L_1	0.21

a_2 is the life adjustment factor for bearing material. $a_2 = 1$ for air-melted AISI 52100 and $a_2 = 0.5$ for air-melted AISI 440C. With improved steel processing higher values of a_2 may be obtained. See ABMA Standard 9 for further information.

a_3 is the life adjustment factor for application conditions. a_3 has a nominal value of 1.0. Higher or lower values are possible and are discussed in ABMA Standard 9.

TABLE 12.1, Part 1
Values of f_{cm} for use with newton & millimetre units

$(D_w/d_p) \cos \alpha$	f_1	0.515	0.52	0.52	0.52	0.53	0.54	0.54	0.54	0.57
	f_0	0.515	0.52	0.53	0.54	0.54	0.54	0.56	0.60	0.57
	0.05	68.15	60.80	56.58	53.34	49.45	46.48	43.39	39.01	37.80
	0.10	81.07	72.68	68.77	65.61	59.71	55.29	52.69	48.59	44.94
	0.12	83.92	74.85	71.71	68.85	62.10	57.23	54.94	51.18	46.51
	0.14	85.83	76.58	73.85	71.33	63.83	58.53	56.56	53.21	47.58
	0.16	86.98	77.61	75.31	73.11	64.96	59.33	57.66	55.50	48.20
	0.18	87.49	78.08	76.15	74.30	65.57	59.67	58.29	55.80	48.50
	0.20	87.48	78.88	76.83	74.93	65.74	59.66	58.53	56.42	48.48
	0.22	86.98	79.18	76.35	75.09	65.53	59.32	58.41	56.68	48.24
	0.24	86.09	76.83	75.82	74.79	65.00	58.72	58.01	56.59	47.75
	0.26	84.89	75.75	74.95	74.14	64.19	57.90	57.33	56.20	47.03
	0.28	83.41	74.41	73.80	73.15	63.17	56.89	56.45	55.54	46.24
	0.30	81.67	72.88	72.40	71.90	61.93	55.71	55.37	54.89	45.28
	0.32	79.74	71.15	70.79	73.01	60.53	54.39	54.13	54.39	44.20
	0.34	77.65	69.28	69.00	68.72	58.97	52.95	52.59	52.35	43.04
	0.36	75.40	67.29	67.07	66.85	57.29	51.43	51.29	50.96	41.81

TABLE 12.2, Part 2
Values of f_{cm} for use with pound & inch units

$(D_w/d_p) \cos \alpha$	f_1	0.515	0.52	0.52	0.52	0.53	0.54	0.54	0.54	0.57
	f_0	0.515	0.52	0.53	0.54	0.54	0.54	0.56	0.60	0.57
	0.05	5175	4618	4297	4051	3756	3530	3296	2963	2870
	0.10	6157	5520	5222	4983	4534	4199	4001	3691	3413
	0.12	6373	5685	5446	5229	4716	4346	4172	3887	3532
	0.14	6518	5816	5608	5417	4848	4445	4295	4040	3613
	0.16	6605	5894	5719	5552	4934	4506	4378	4215	3661
	0.18	6644	5929	5784	5642	4979	4532	4427	4237	3683
	0.20	6643	5990	5834	5690	4992	4531	4445	4285	3682
	0.22	6605	6014	5798	5702	4976	4505	4436	4304	3663
	0.24	6538	5834	5758	5680	4936	4459	4404	4298	3626
	0.26	6447	5753	5691	5630	4875	4397	4354	4268	3572
	0.28	6334	5651	5604	5555	4797	4320	4286	4217	3511
	0.30	6202	5534	5498	5460	4703	4230	4204	4168	3439
	0.32	6055	5403	5376	5347	4597	4130	4111	4130	3357
	0.34	5897	5261	5240	5218	4479	4021	3994	3975	3268
	0.36	5727	5110	5093	5077	4351	3905	3895	3870	3175

FIGURE II, Part 1
for use with newton and millimetre units
LOADED CONTACT ANGLE DETERMINATION

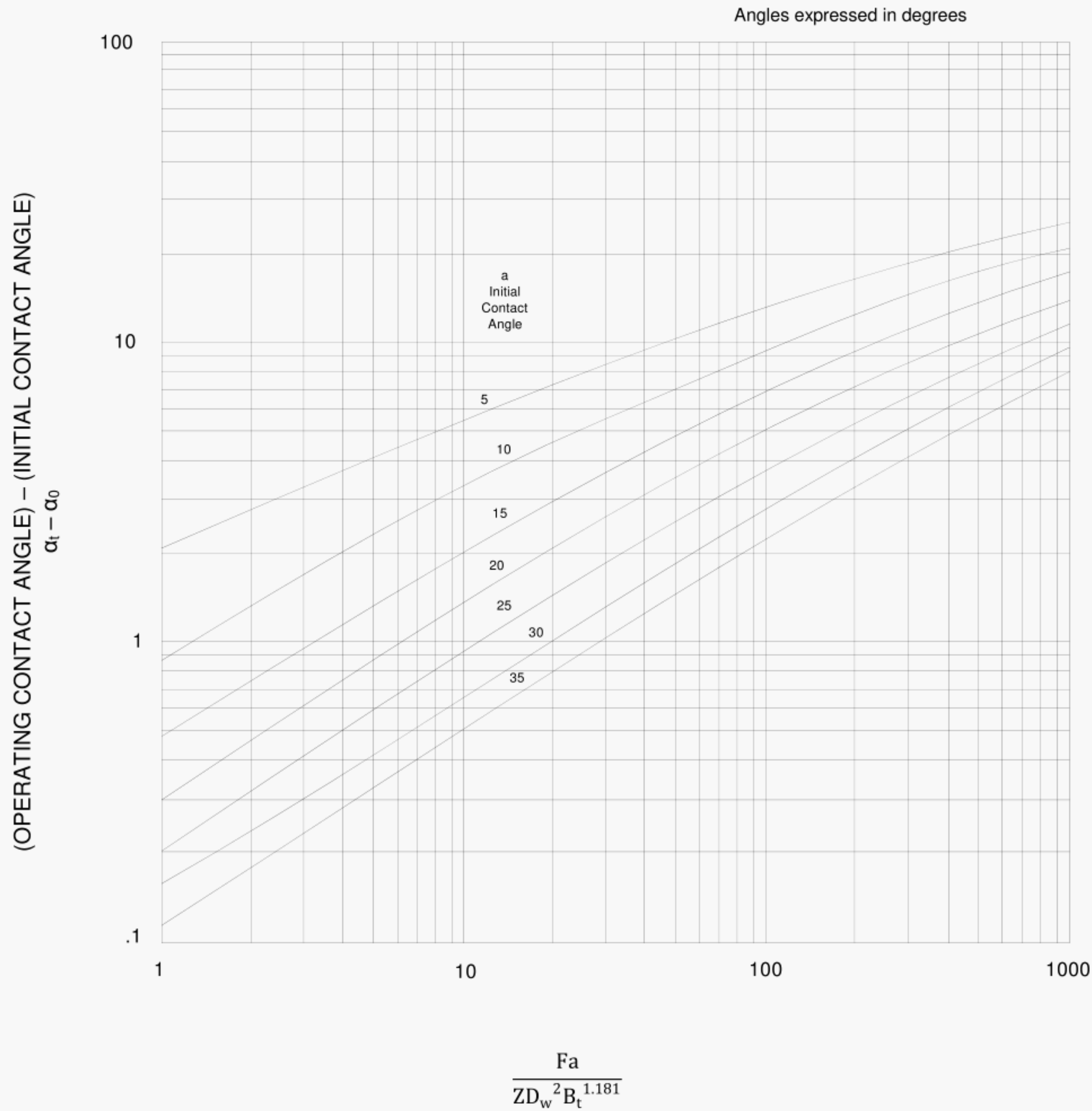


FIGURE II, Part 2
for use with pound and inch units
LOADED CONTACT ANGLE DETERMINATION

