CUSTOM PRECISION BEARINGS, INC.

Products and Services

- Precision Spherical Roller Bearings
- Custom Bearing Housed Units
- Precision Roll Assemblies
  - Design, Analyze, Build
  - Chrome
  - Chill
  - Elastomer Covered
- Consulting Engineering - Rolling Bearings
  - Design, Analysis, System Analysis
  - Trouble Shooting, Damage/Failure Analysis

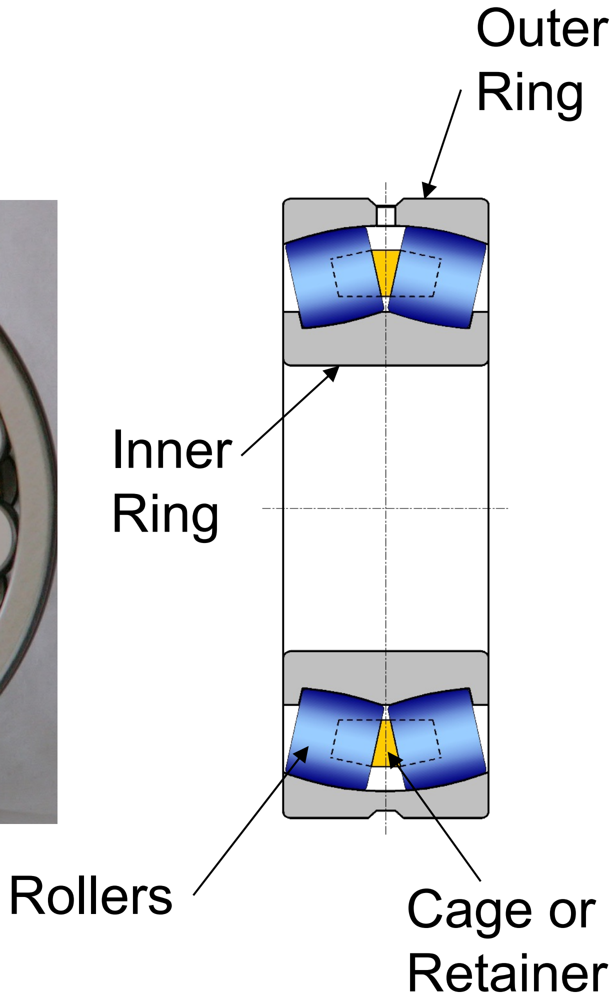
Principals

- Charlie Foley
  - President/Owner
- Brian Suda
  - Production Manager/Owner
- Michael Antol
  - Sales & Marketing – PH 860-347-5227
- Gene Pfaffenberger
  - Consulting Engineer

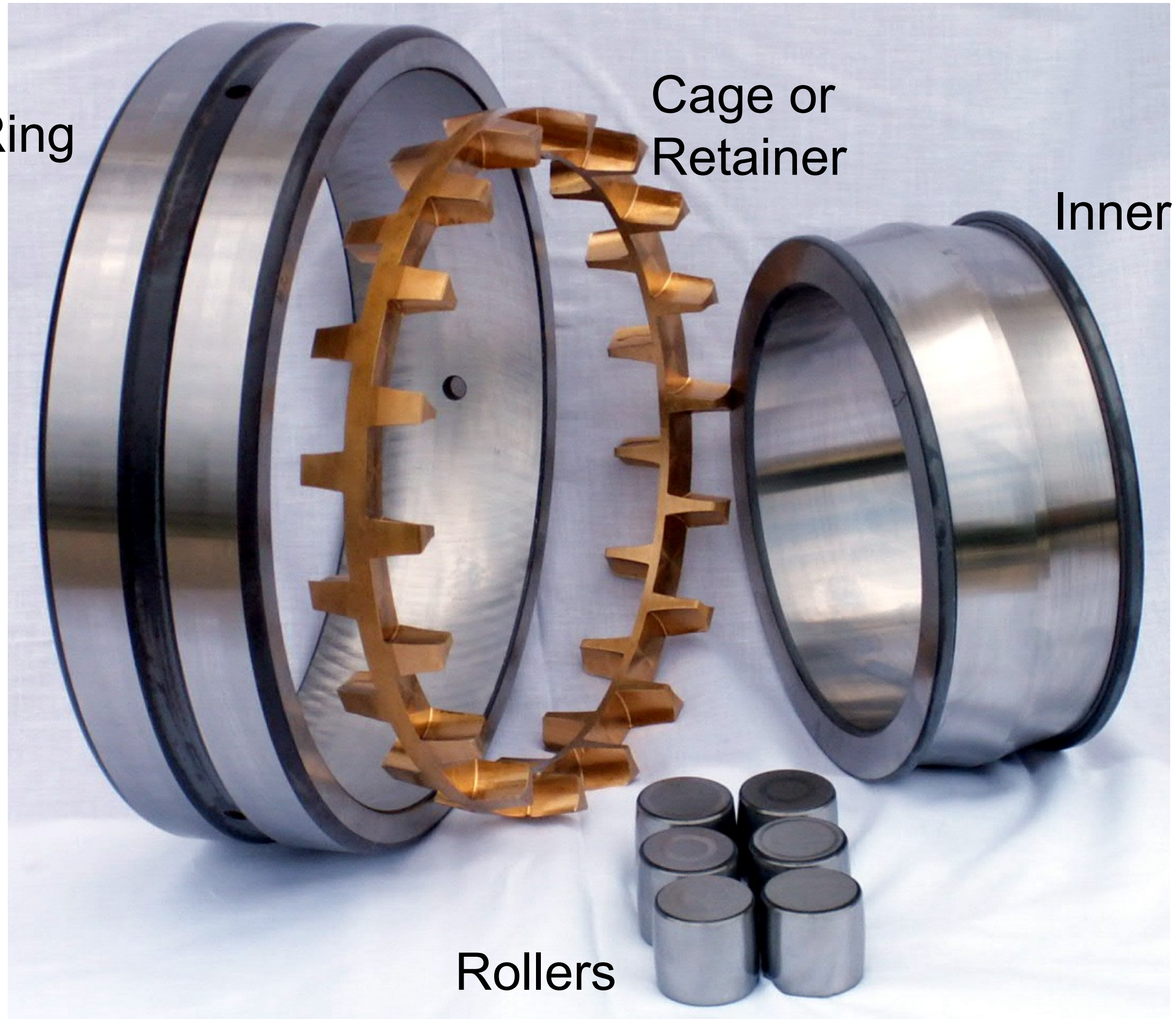
Spherical Roller Bearings

- High Radial Load Capacity
- Combined Radial/Axial Load Capability
- Inherently Self-Aligning
- Relatively Low Speed Capability
- Available in a Variety of Boundary Plans
- Available with Cylindrical or Tapered Bore

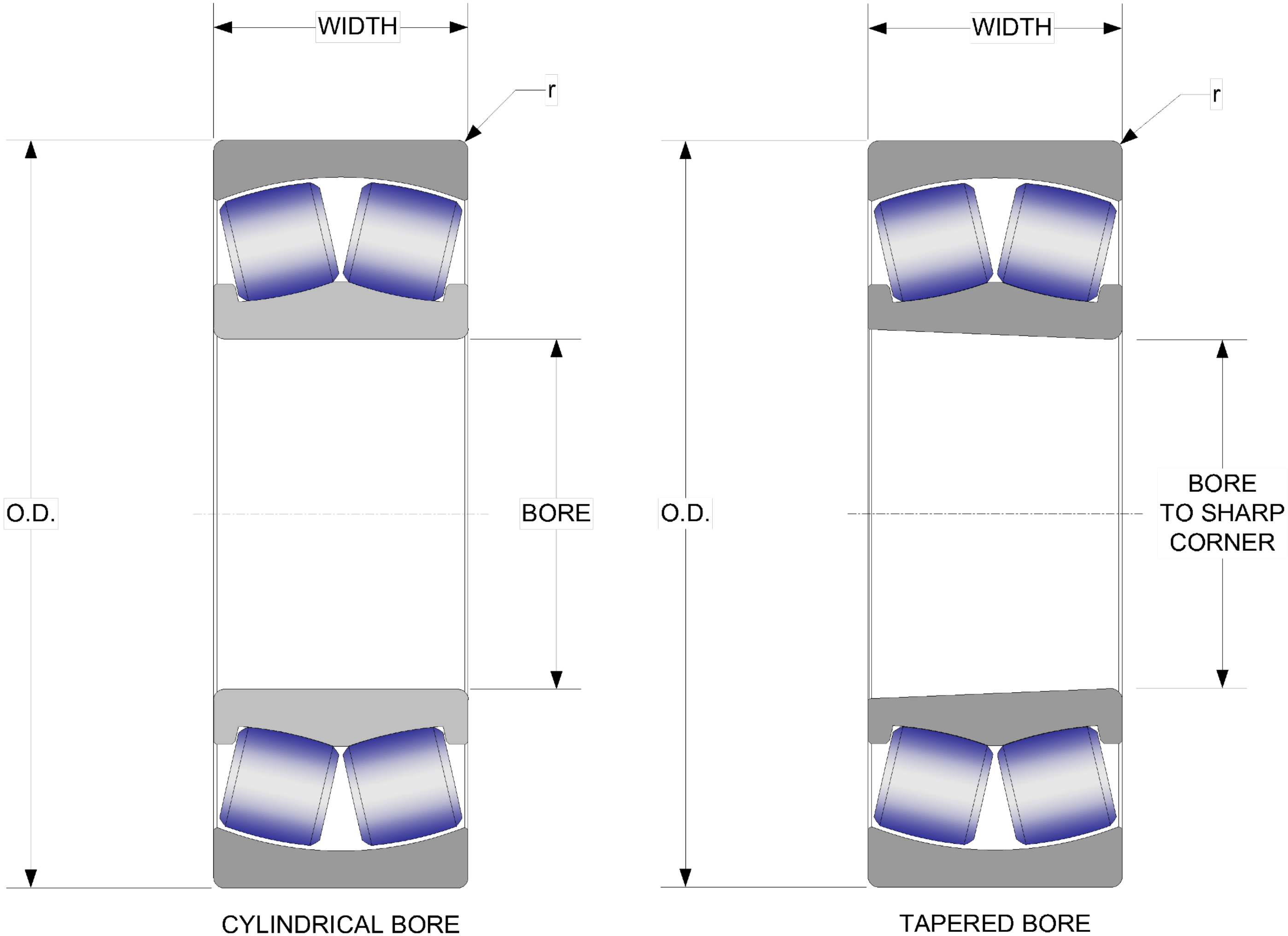
Spherical Roller Bearings

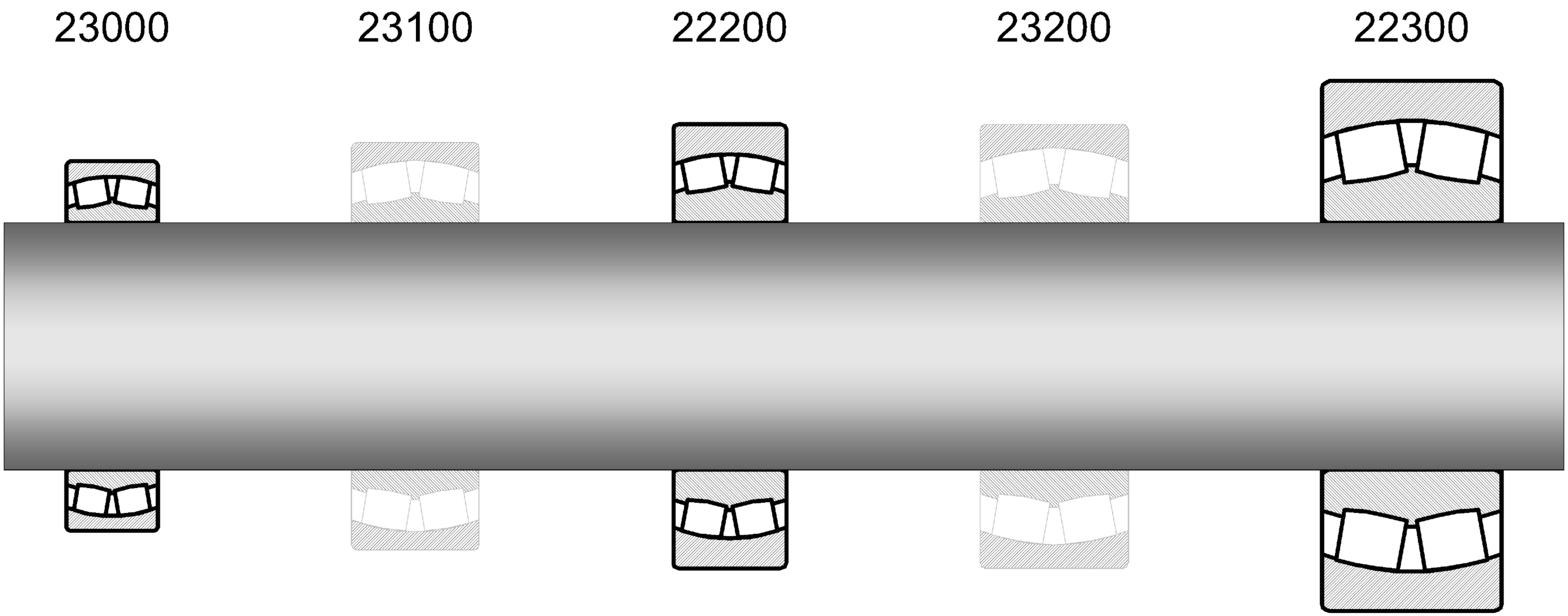


Spherical Roller Bearing Components



Spherical Roller Bearing Boundary Dimensions




23000
23100
22200
23200
22300

Spherical Roller Bearing Nomenclature

2 22 16 K . 50M . RC

2	Spherical Roller Bearing
22	Dimension Series (22, 23, 30, etc.)
16	1/5 of Bore Diameter, mm (e.g., 5X16 = 80mm Bore)
K	Tapered Bore
00M	Runout, $\mu\cdot$in (50M = 0.000050 in TIR)
RC	Reduced Clearance

Spherical Roller Boundary Dimensions

Size No.	Bore Size	Dimension Series														
		30			31			22			32			23		
		O.D.	Width	Corner	O.D.	Width	Corner	O.D.	Width	Corner	O.D.	Width	Corner	O.D.	Width	Corner
00	10	26	12	0.3	–	–	–	30	14	0.6	30	14.3	0.6	35	17	0.6
01	12	28	12	0.3	–	–	–	32	14	0.6	32	15.9	0.6	37	17	1
02	15	32	13	0.3	–	–	–	35	14	0.6	35	15.9	0.6	42	17	1
03	17	35	14	0.3	–	–	–	40	16	0.6	40	17.5	0.6	47	19	1
04	20	42	16	0.6	–	–	–	47	18	1	47	20.6	1	52	21	1.1
	22	44	16	0.6	–	–	–	50	18	1	50	20.6	1	56	21	1.1
05	25	47	16	0.6	–	–	–	52	18	1	52	20.6	1	62	24	1.1
	28	52	18	0.6	–	–	–	58	19	1	58	23	1	68	24	1.1
06	30	55	19	1	–	–	–	62	20	1	62	23.8	1	72	27	1.1
	32	58	20	1	–	–	–	65	21	1	65	25	1	75	28	1.1
07	35	62	20	1	–	–	–	**72**	**23**	**1.1**	72	27	1.1	**80**	**31**	**1.5**
08	40	68	21	1	–	–	–	**80**	**23**	**1.1**	80	30.2	1.1	**90**	**33**	**1.5**
09	45	75	23	1	–	–	–	**85**	**23**	**1.1**	85	30.2	1.1	**100**	**36**	**1.5**
10	50	80	23	1	–	–	–	**90**	**23**	**1.1**	90	30.2	1.1	**110**	**40**	**2**
11	55	90	26	1.1	–	–	–	**100**	**25**	**1.5**	100	33.3	1.5	**120**	**43**	**2**
12	60	95	26	1.1	–	–	–	**110**	**28**	**1.5**	110	36.5	1.5	**130**	**46**	**2.1**
13	65	100	26	1.1	–	–	–	**120**	**31**	**1.5**	120	38.1	1.5	**140**	**48**	**2.1**
14	70	110	30	1.1	–	–	–	**125**	**31**	**1.5**	125	39.7	1.5	**150**	**51**	**2.1**
15	75	115	30	1.1	–	–	–	**130**	**31**	**1.5**	130	41.3	1.5	**160**	**55**	**2.1**
16	80	125	34	1.1	–	–	–	**140**	**33**	**2**	140	44.4	2	**170**	**58**	**2.1**
17	85	130	34	1.1	–	–	–	**150**	**36**	**2**	150	49.2	2	**180**	**60**	**3**
18	90	140	37	1.5	–	–	–	**160**	**40**	**2**	160	52.4	2	**190**	**64**	**3**
19	95	145	37	1.5	–	–	–	**170**	**43**	**2.1**	170	55.6	2.1	**200**	**67**	**3**
20	100	150	37	1.5	165	52	2	**180**	**46**	**2.1**	180	60.3	2.1	**215**	**73**	**3**
21	105	160	41	2	175	56	2	**190**	**50**	**2.1**	190	65.1	2.1	**225**	**77**	**3**
22	110	**170**	**45**	**2**	180	56	2	**200**	**53**	**2.1**	200	69.8	2.1	**240**	**80**	**3**
24	120	**180**	**46**	**2**	200	62	2	**215**	**58**	**2.1**	215	76	2.1	**260**	**86**	**3**
26	130	**200**	**52**	**2**	210	64	2	**230**	**64**	**3**	230	80	3	**280**	**93**	**4**
28	140	**210**	**53**	**2**	225	68	2.1	**250**	**68**	**3**	250	88	3	**300**	**102**	**4**
30	150	**225**	**56**	**2.1**	250	80	2.1	**270**	**73**	**3**	270	96	3	**320**	**108**	**4**
32	160	**240**	**60**	**2.1**	270	86	2.1	**290**	**80**	**3**	290	104	3	**340**	**114**	**4**
34	170	**260**	**67**	**2.1**	280	88	2.1	**310**	**86**	**4**	310	110	4	**360**	**120**	**4**
36	180	**280**	**74**	**2.1**	300	96	3	**320**	**86**	**4**	320	112	4	**380**	**126**	**4**
38	190	**290**	**75**	**2.1**	320	104	3	340	92	4	340	120	4	400	132	5
40	200	**310**	**82**	**2.1**	340	112	3	360	98	4	360	128	4	420	138	5
42	220	**340**	**90**	**3**	370	120	3	400	106	4	400	144	4	460	145	5
44	240	**360**	**92**	**3**	400	128	4	440	120	4	440	160	4	500	155	5
46	260	400	104	4	440	144	4	480	130	5	480	174	5	540	165	6
48	280	420	106	4	460	146	4	500	130	5	500	176	5	580	175	6
50	300	460	118	4	500	160	5	540	140	5	540	192	5	620	185	7.5

Standard Clearances

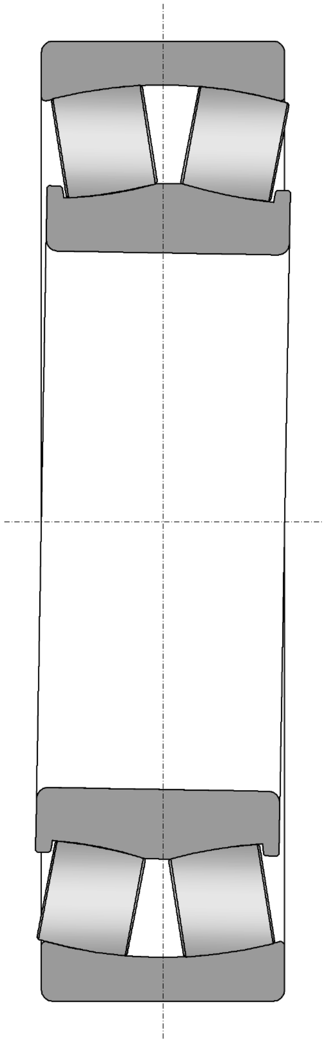
ANSI/ABMA Std 20 - 1996
Table A23

RADIAL INTERNAL CLEARANCE VALUES FOR
DOUBLE ROW, SELF-ALIGNING ROLLER BEARINGS WITH TAPERED BORE

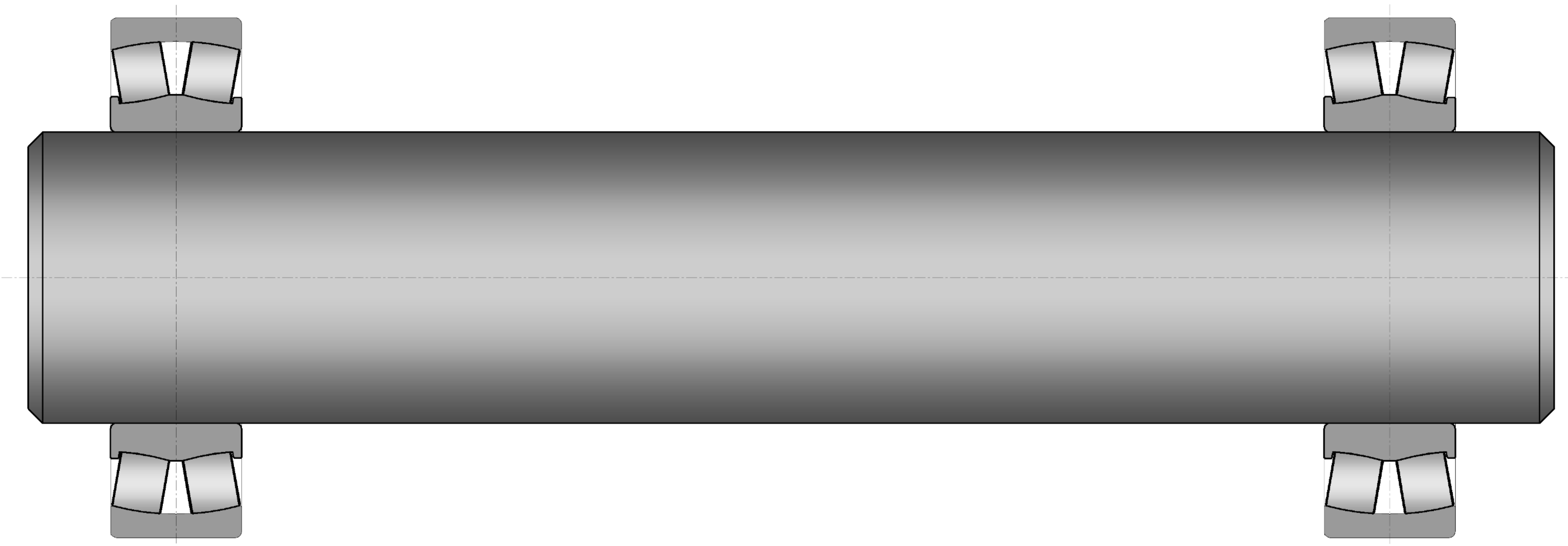
Clearance values in 0.0001 inch

Bearing Bore mm		Group 2 (C2)		Group N (C0)		Group 3 (C3)		Group 4 (C4)		Group 5 (C5)	
over	incl.	min	max	min	max	min	max	min	max	min	max
24	30	8	12	12	16	16	22	22	30	30	37
30	40	10	14	14	20	20	26	26	33	33	41
40	50	12	18	18	24	24	31	31	39	39	51
50	65	16	22	22	30	30	37	37	47	47	63
65	80	20	28	28	37	37	47	47	59	59	79
80	100	22	31	31	43	43	55	55	71	71	91
100	120	26	39	39	53	53	67	67	87	87	110
120	140	31	47	47	63	63	79	79	102	102	130
140	160	35	51	51	71	71	91	91	118	118	150
160	180	39	55	55	79	79	102	102	134	134	169
180	200	43	63	63	87	87	114	114	146	146	185
200	225	47	71	71	98	98	126	126	161	161	205
225	250	55	79	79	106	106	138	138	177	177	224

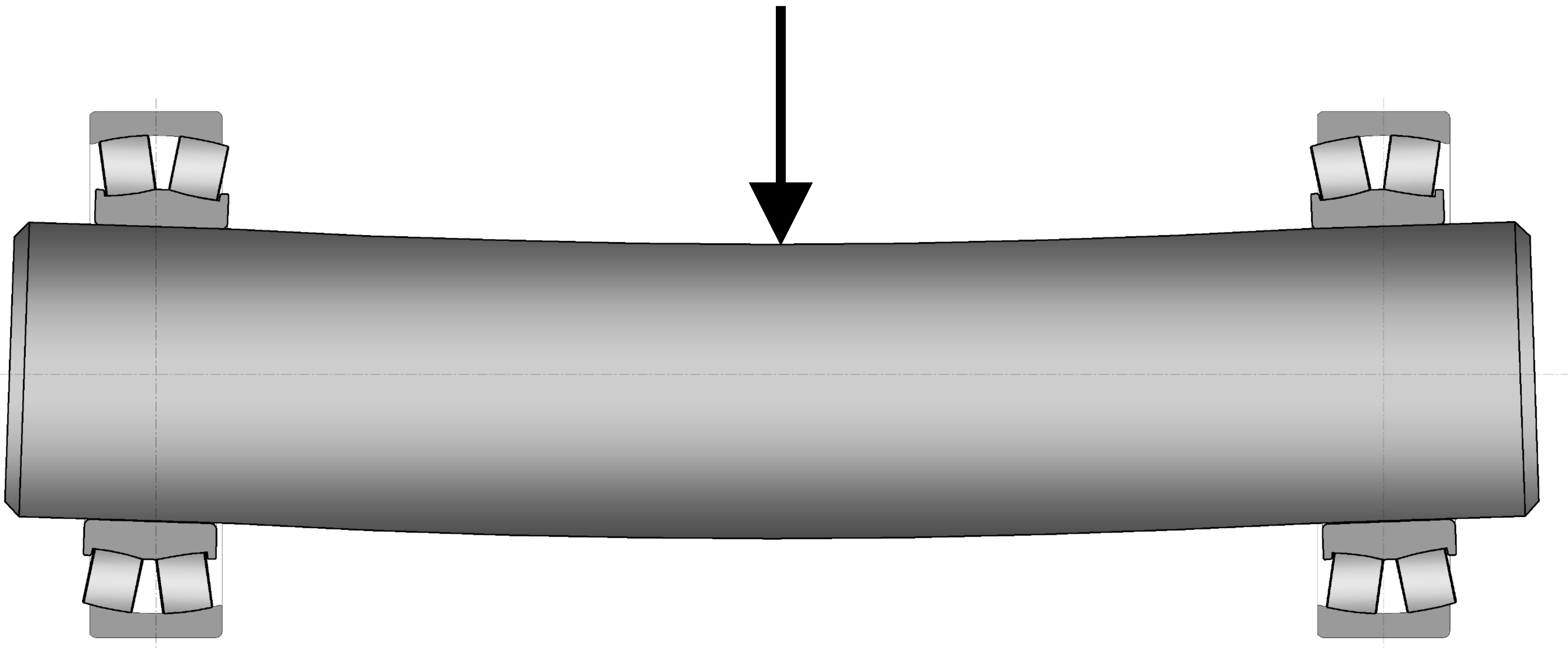
Principle of Spherical Roller Bearing



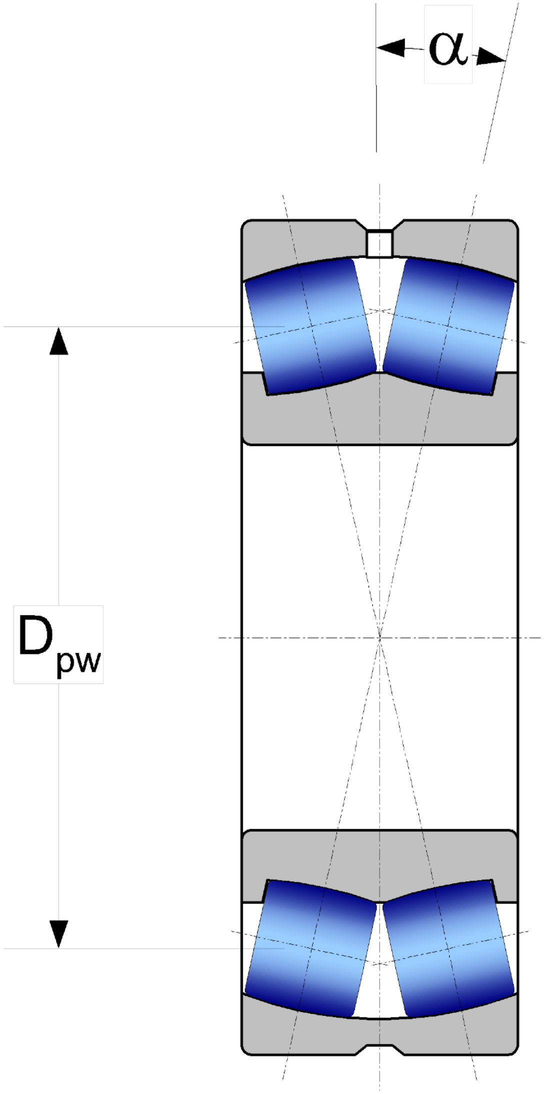
Principle of Spherical Roller Bearing

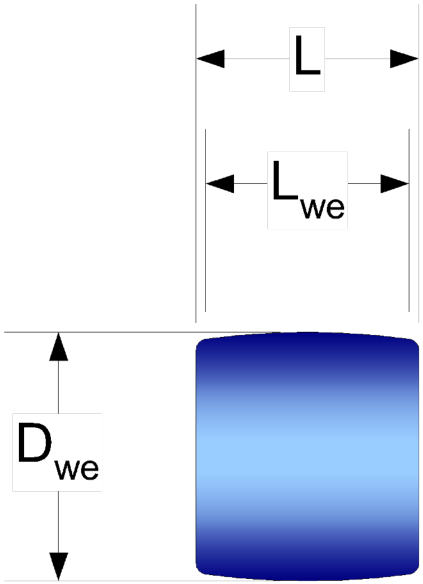


Principle of Spherical Roller Bearing

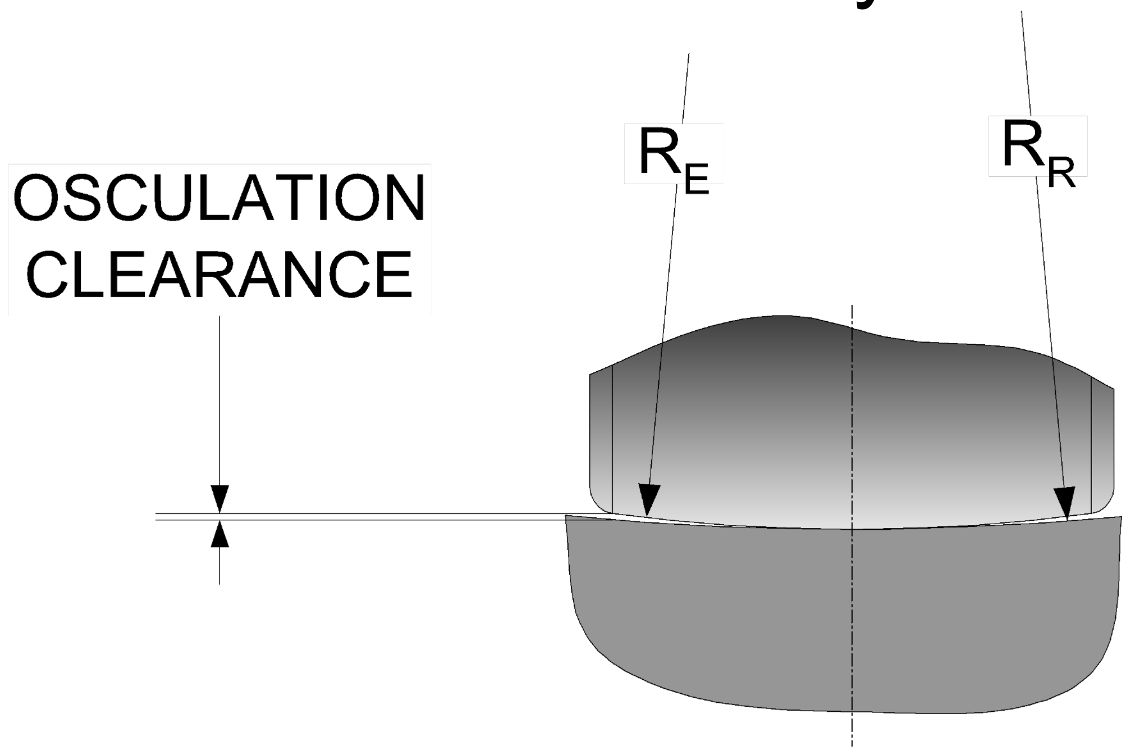


Spherical Roller Bearing Geometry





Spherical Roller Bearing Contact Geometry



$$\text{OSCULATION} = \frac{R_E}{R_R}, \%$$

Standard Inner Ring Tolerances

All Tolerances in 0.0001 in

Bore, mm		Bore Diameter Tolerance			Radial Runout*			Ring Width Tolerance	
Over	Incl	RBEC Class			RBEC Class			RBEC Class	RBEC Class
		1	3	5	1	3	5	1 & 3	5
-	10	3	3	2	4	2.5	1.5	47	16
10	18	3	3	2	4	3	1.5	47	31
18	30	4	3	2.5	5	3	1.5	47	47
30	50	4.5	4	3	6	4	2	47	47
50	80	6	4.5	3.5	8	4	2	59	59
80	120	8	6	4	10	5	2.5	79	79
120	180	10	7	5	12	7	3	98	98
180	250	12	8.5	6	16	8	4	118	118

*Maximum, for Assembled Bearing

Standard Outer Ring Tolerances

All Tolerances in 0.0001 in

O. D., mm		O.D. Tolerance			Radial Runout*			Ring Width Tolerance	
Over	Incl	RBEC Class			RBEC Class			RBEC Class	RBEC Class
		1	3	5	1	3	5	1 & 3	5
18	30	3.5	3	2.5	6	3.5	2.5	47	16
30	50	4.5	3.5	3	8	4	3	47	31
50	80	5	4.5	3.5	10	5	3	47	47
80	120	6	5	4	14	7	4	47	47
120	150	7	6	4.5	16	8	4.5	59	59
150	180	10	7	5	18	9	5	79	79
180	250	12	8	6	20	10	6	98	98
250	315	14	10	7	24	12	7	118	118

*Maximum, for Assembled Bearing

Recommended Inner Ring Fits

Rotation	Radial Load		Over	Incl	Fit
Inner Ring Rotating in Relation to Load Direction or Load Direction is Indeterminate	Light (< 0.08C)		0	40	j6
			40	100	k6
			100	200	m6
	Normal (> 0.08C <= 0.18C)		0	40	k5
			40	65	m5
			65	100	m6
			100	140	n6
			140	280	p6
			280	500	r6
			500	--	r7
	Heavy (> 0.18C)		0	40	m5
			40	65	m6
			65	100	n6
			100	140	p6
			140	200	r6
			200	--	r7
Inner Ring Stationary in Relation to Load Direction	All Loads	Inner Ring Easily Axially Displaceable	All Sizes		g6
		Inner Ring Not Easily Axially Displaceable	All Sizes		h6

Recommended Outer Ring Fits

<table>
<tr><th>Housing Construction</th><th colspan="3">Operating Condition</th><th>Class of Fit</th><th>Remarks</th></tr>
<tr><td rowspan="5">Housing Not Split Radially</td><td rowspan="3">Housing Rotating in Relation to Direction of Load</td><td colspan="2">Heavy Loads on Bearings in Thin-walled Housings</td><td>P6</td><td rowspan="4">Outer Ring Not Axially Displaceable</td></tr>
<tr><td colspan="2">Normal and Heavy Loads</td><td>N6</td></tr>
<tr><td colspan="2">Light Loads</td><td rowspan="2">M6</td></tr>
<tr><td rowspan="3">Direction of Load Indeterminate</td><td colspan="2">Heavy Shock Loads</td></tr>
<tr><td colspan="2">Heavy and normal loads where outer ring does not have to be axially displaceable</td><td>K6</td><td>Outer Ring Normally Not Axially Displaceable</td></tr>
<tr><td rowspan="5">Housing Split or Not Split Radially</td><td colspan="2">Normal and Light Loads Where Displaceability of Outer Ring is Desirable</td><td rowspan="2">J6</td><td rowspan="2">Outer Ring Normally Axially Displaceable</td></tr>
<tr><td rowspan="4">Housing Stationary in Relation to Direction of Load</td><td colspan="2">Shock Loads, Temporary Complete Unloading</td></tr>
<tr><td rowspan="2">All Loads</td><td>Housing Not Split Radially</td><td>H6</td><td rowspan="3">Outer Ring Easily Axially Displaceable</td></tr>
<tr><td>Housing Split Radially</td><td>H7</td></tr>
<tr><td colspan="2">Heat Applied Through Shaft</td><td>G7</td></tr>
</table>

Inner Ring Fitting Practice

Bore, mm		Bore Tolerance, +0		Shaft Tolerance by Fit Class									
Over	Incl	RBEC-1	RBEC-5	g6	h6	h5	j5	j6	k5	k6	m5	m6	n6
10	18	-3	-2										
18	30	-4	-2.5	-3 -8	0 -5	0 -4	2 -2	3 -2	5 1	6 1	7 3	8 3	11 6
30	50	-4.5	-3	-4 -10	0 -6	0 -4	2 -2	4 -2	5 1	7 1	8 4	10 4	13 7
50	80	-6	-3.5	-4 -11	0 -7	0 -5	2 -3	4 -3	6 1	8 1	10 5	12 5	15 8
80	120	-8	-4	-5 -14	0 -9	0 -6	2 -4	5 -4	7 1	10 1	11 5	14 6	19 10
120	180	-10	-5	-6 -16	0 -10	0 -7	3 -4	6 -4	8 1	11 1	13 6	16 6	22 12
180	250	-12	-6	-6 -18	0 -12	0 -8	3 -5	7 -5	10 2	14 2	14 6	18 6	26 14

All tolerances in 0.0001"

Precision Spherical Roller Bearings

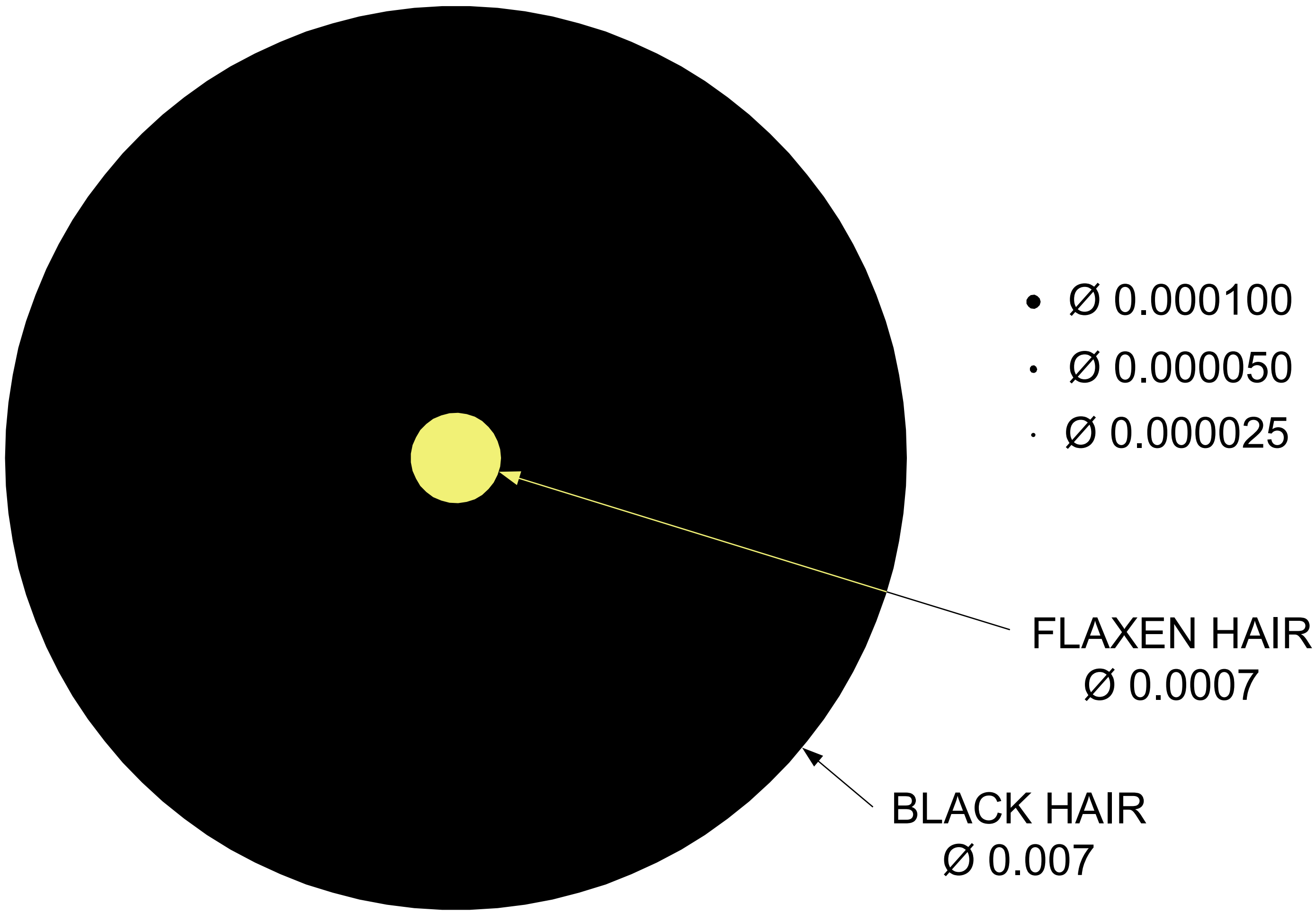
- Reduced Tolerance O.D.
- Precision Run-out (Eccentricity) Tolerance
- Precision Roller Grouping Tolerance
- Special Reduced Internal Clearance
- Inner Ring Run-out High Point Marked
- Take-up and Resultant Torque Marked

Precision Spherical Roller Bearing Tolerances

Tolerances in 0.0001 in

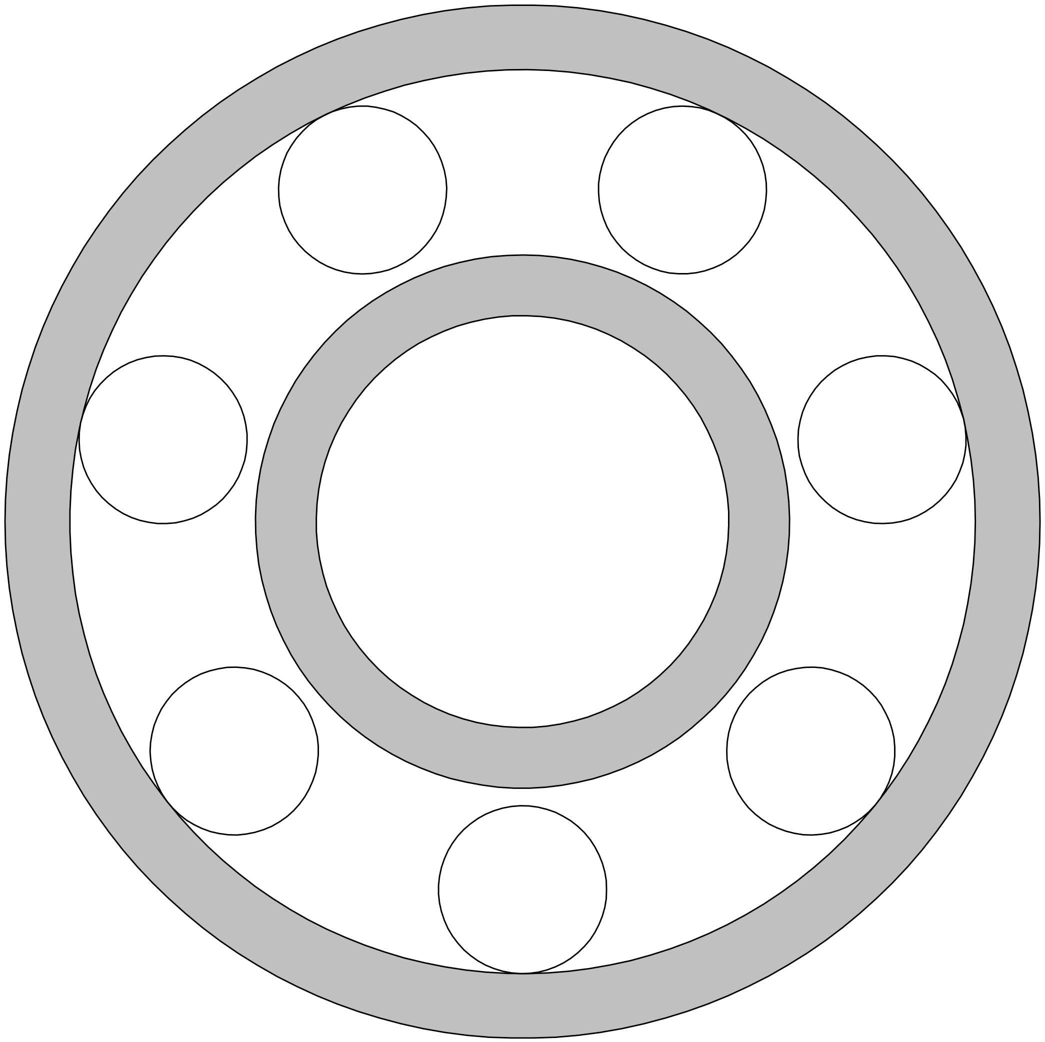
Bearing Bore mm		Maximum Inner Ring Runout (TIR) in an Assembled Bearing				
Over	Incl	RBEC–1	RBEC–3	RBEC–5	Precision	Ultra-Precision
30	50	6	4	2	1	0.5
50	80	8	4	2	1	0.5
80	120	10	5	2.5	1	0.5
120	180	12	7	3	1	0.5
180	250	16	8	4	2	1
250	315	20	10	5	2	1
Roller Segregation		1	1	0.5	–	–

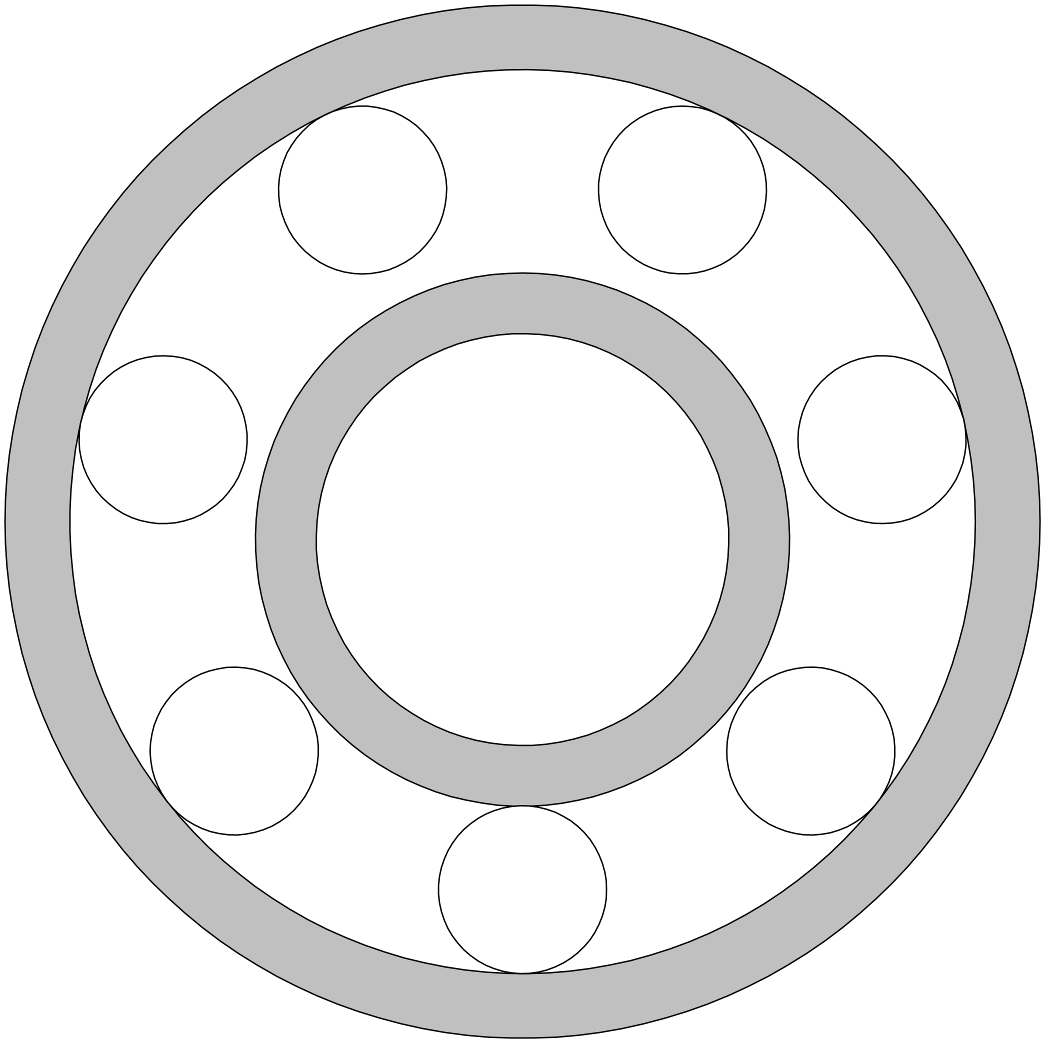
Comparison of Precision Runouts to Human Hair Diameter

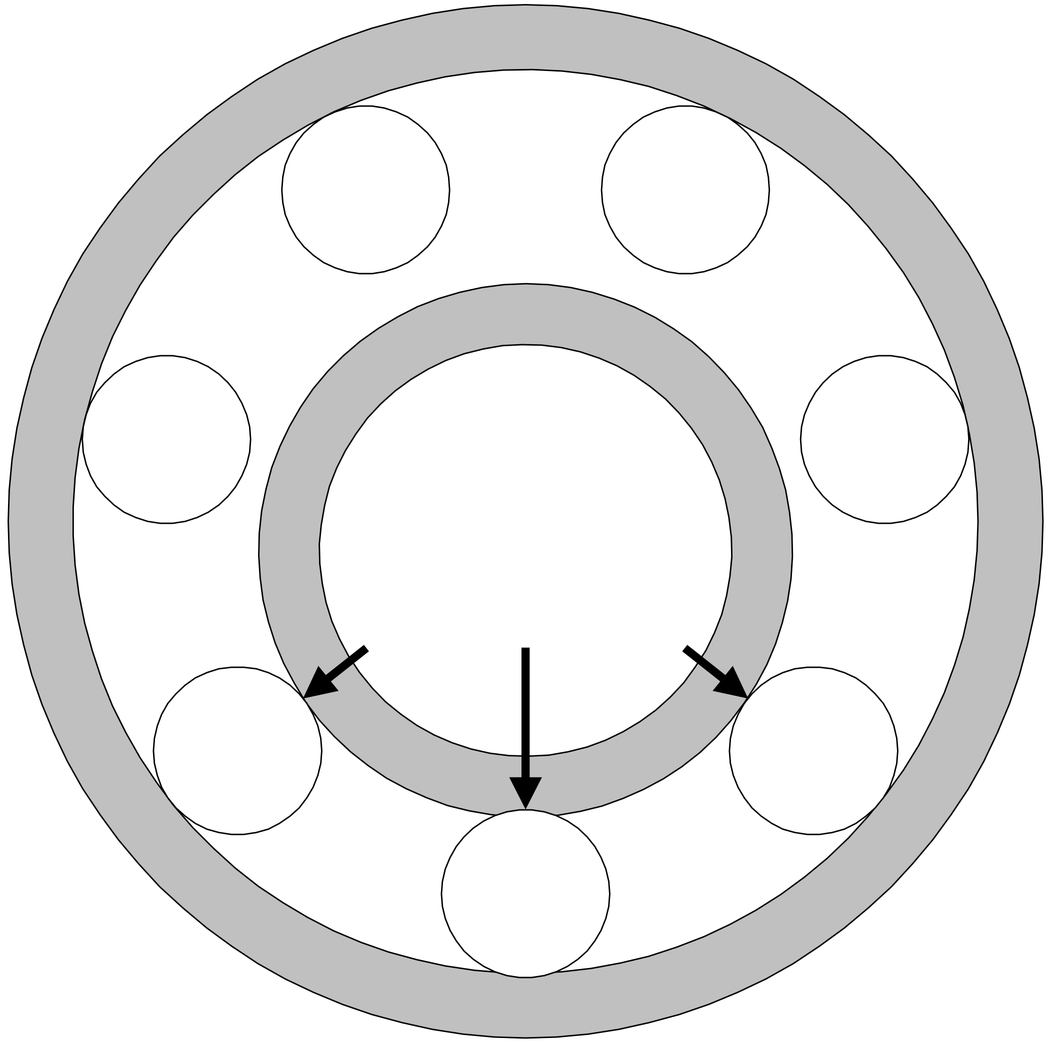


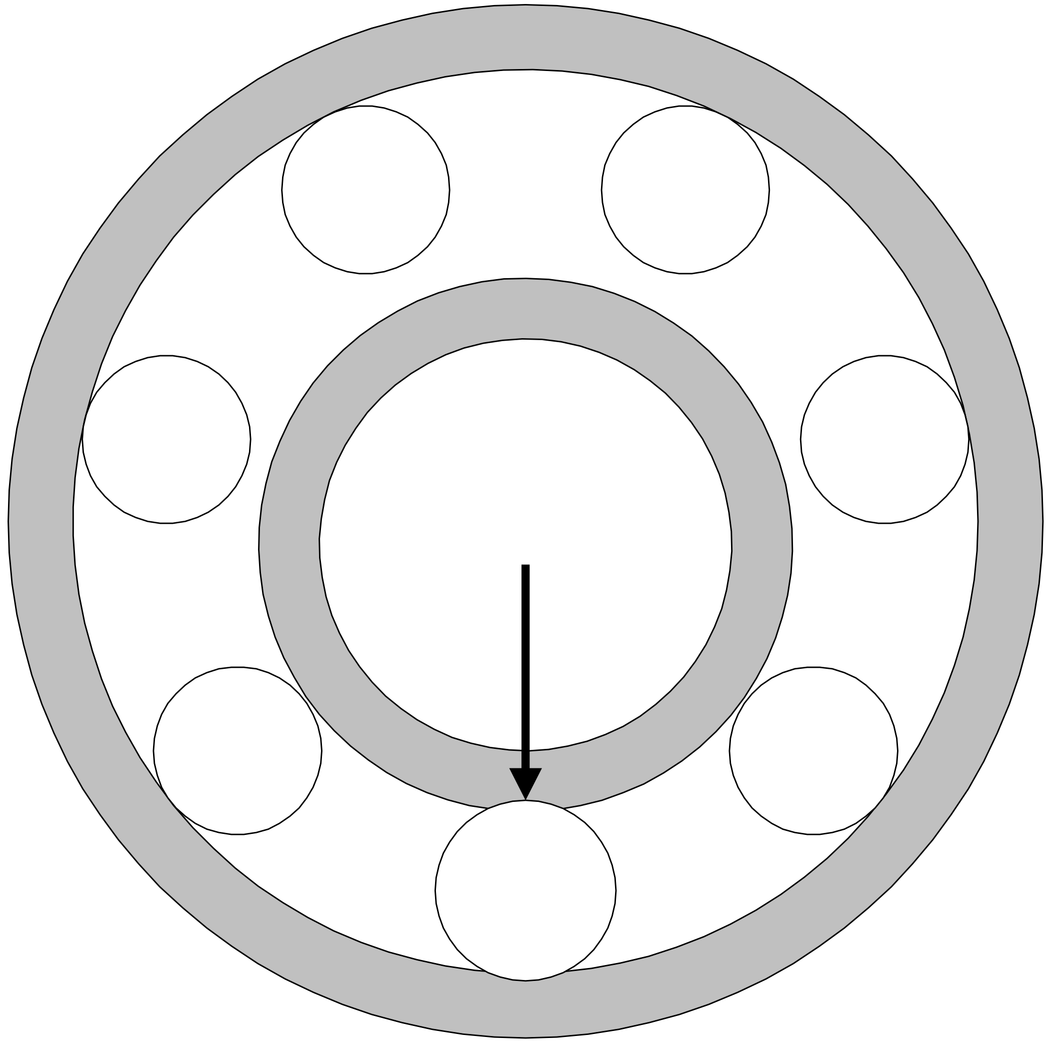
Effect of Roller Size Segregation

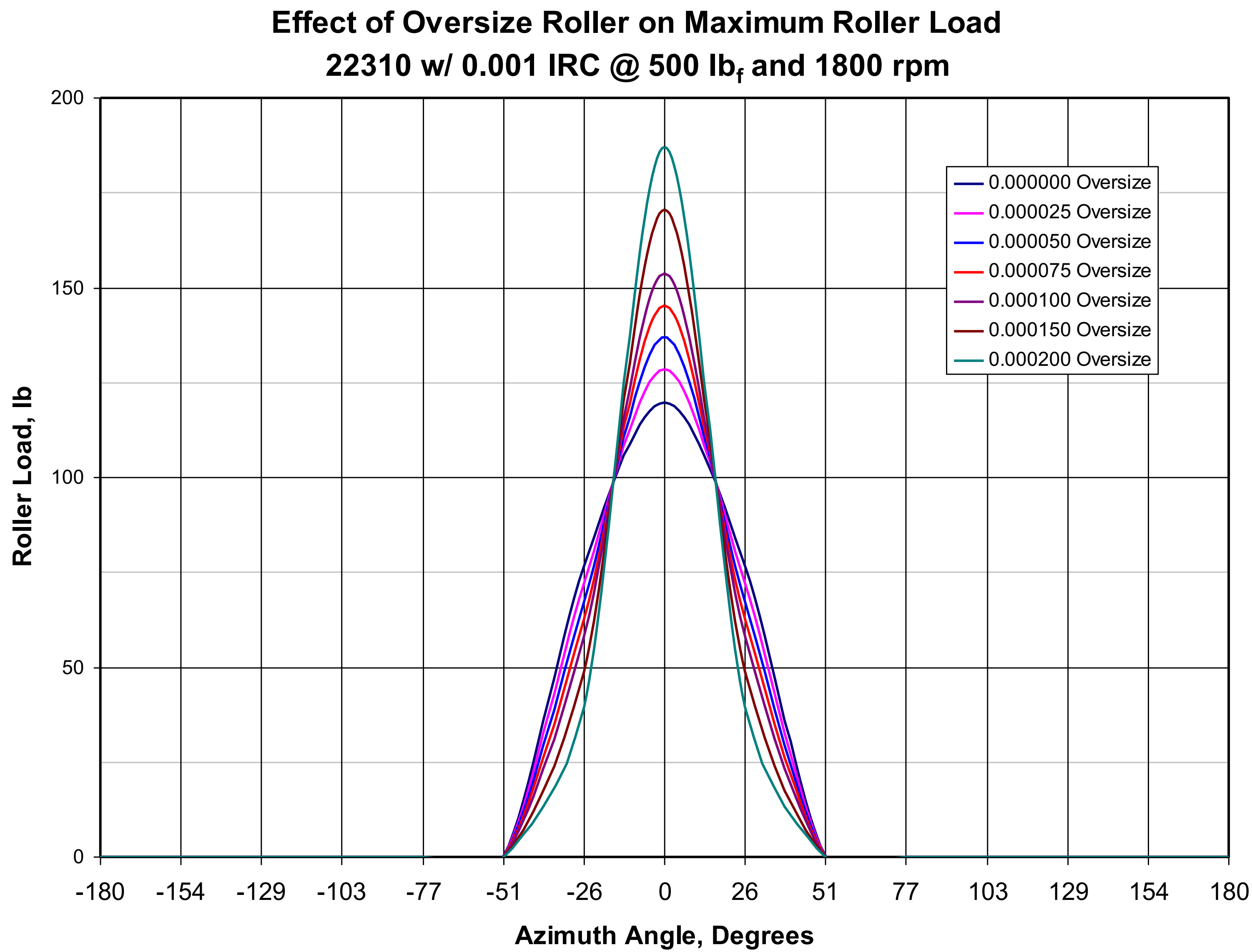
- Non-Repetitive Runout
- Roller Load Distribution
  - Maximum Roller Load
  - Bearing Life
- Noise & Vibration





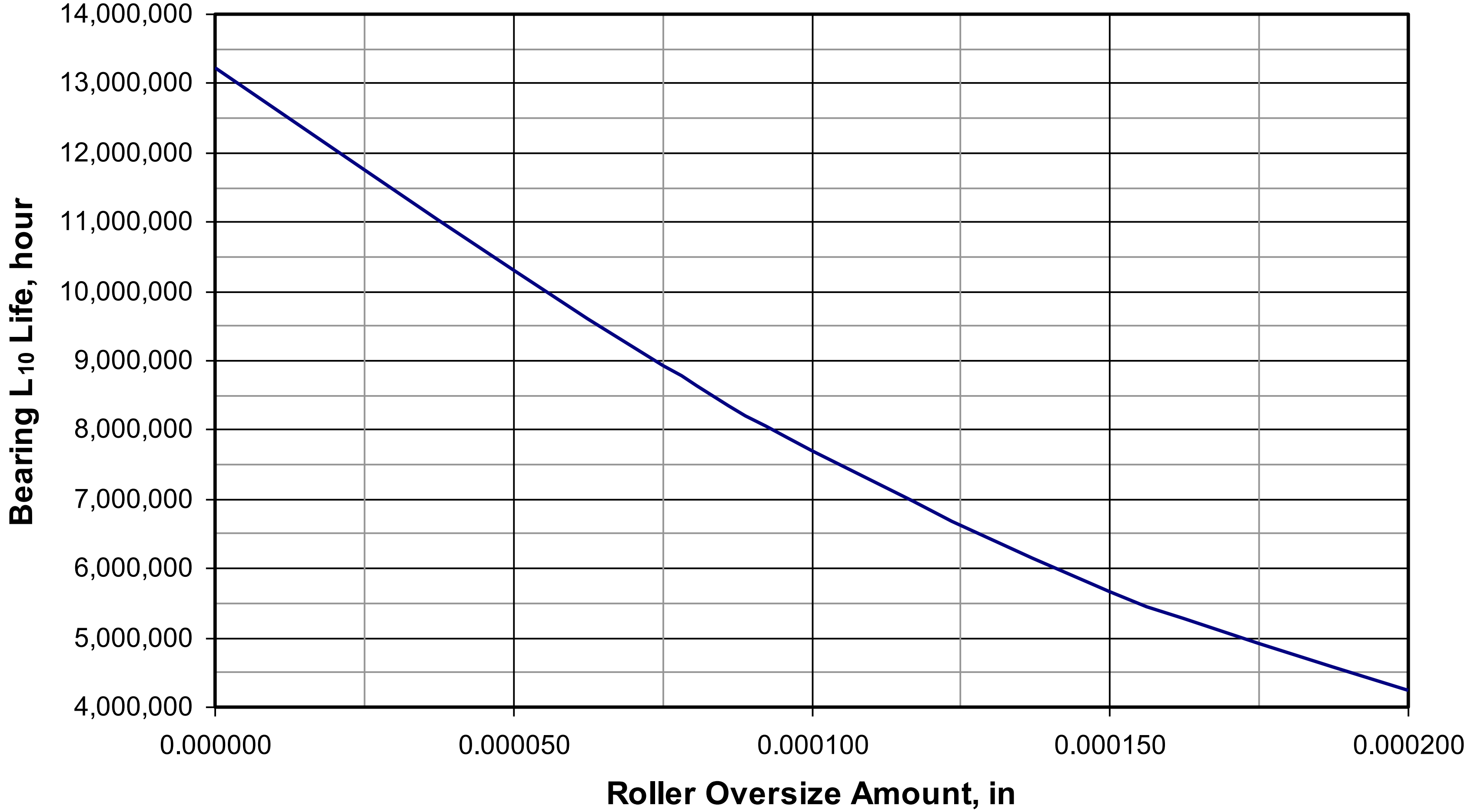




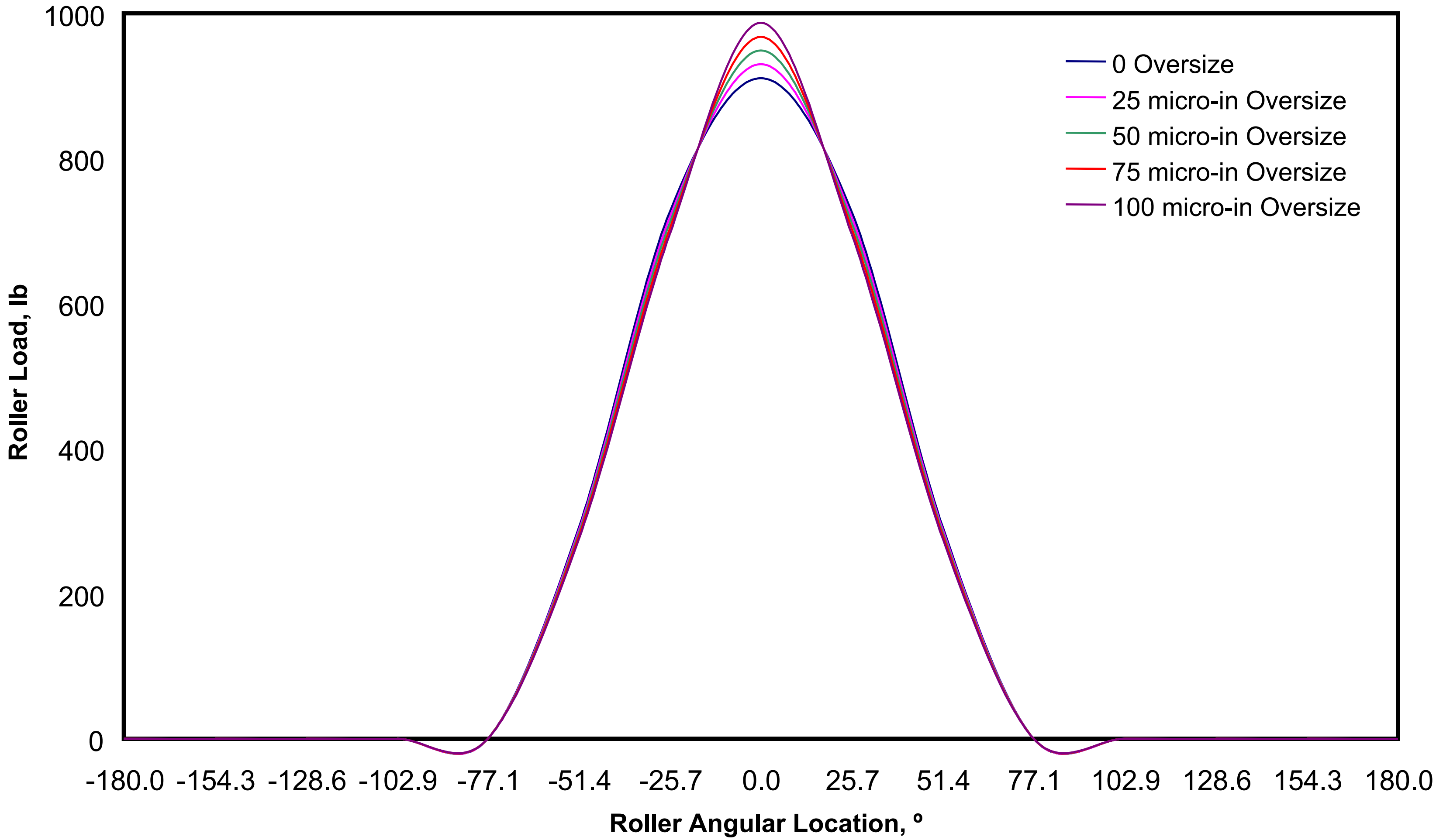


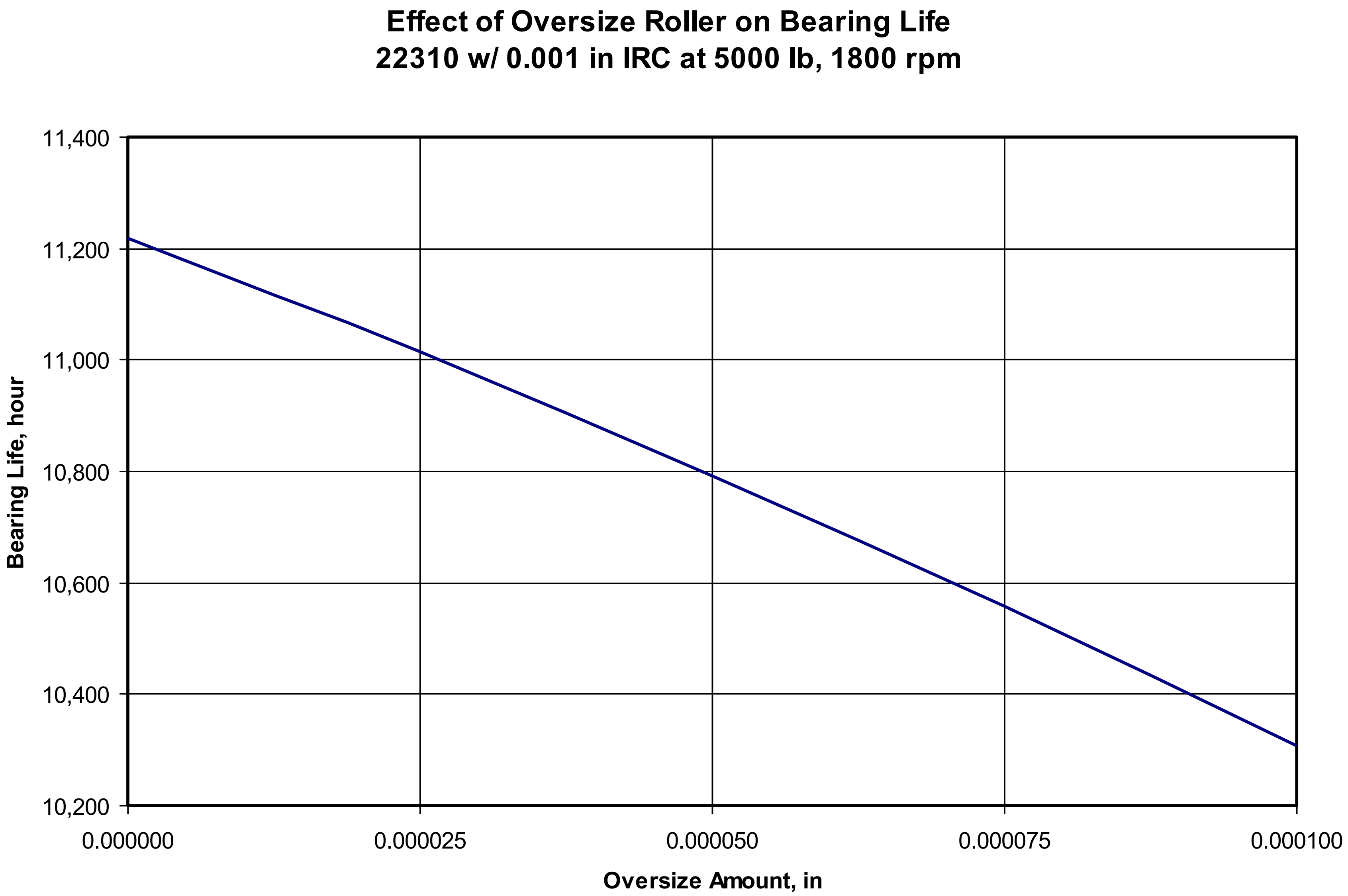
Effect of Oversize Roller on Maximum Roller Load
22310 w/ 0.001 IRC @ 500 lbf and 1800 rpm
200
150
100
50
0
Roller Load, lb
-180
-154
-129
-103
-77
-51
-26
0
26
51
77
103
129
154
180
Azimuth Angle, Degrees
0.000000 Oversize
0.000025 Oversize
0.000050 Oversize
0.000075 Oversize
0.000100 Oversize
0.000150 Oversize
0.000200 Oversize

Effect of Oversize Roller on Bearing L_{10} Life
22310 w/ 0.001 IRC @ 500 lb_f and 1800 rpm

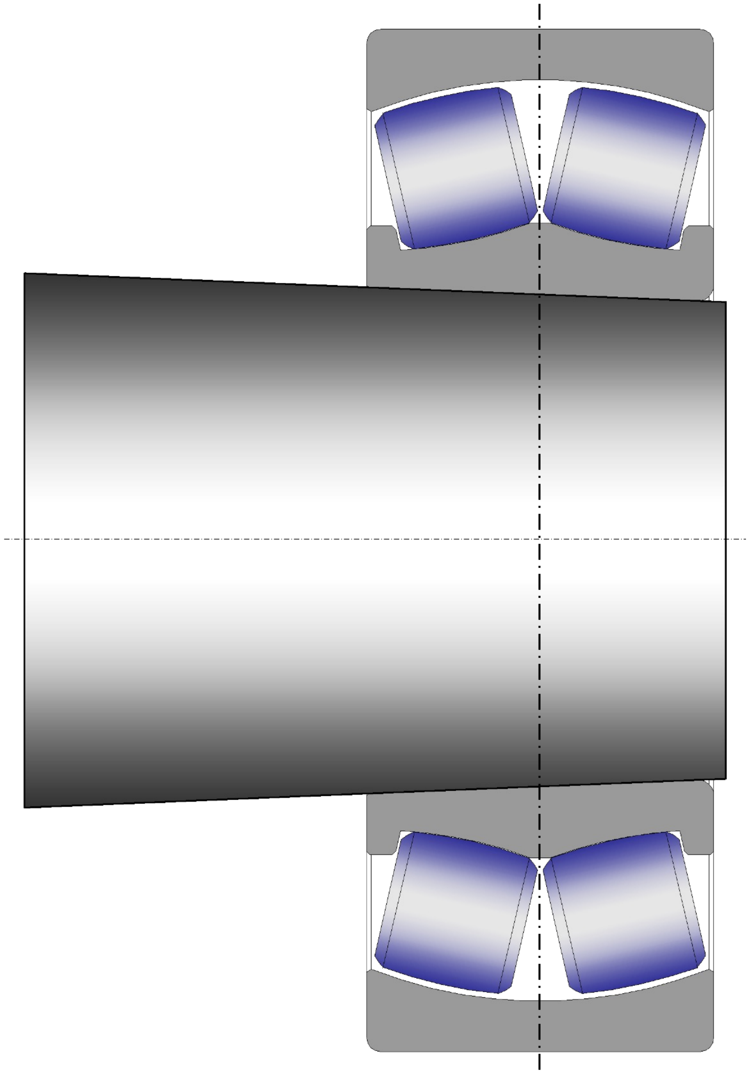


Effect of Oversize Roller on Roller Load Distribution
22310 w/ 0.001 in IRC at 5000 lb, 1800 rpm

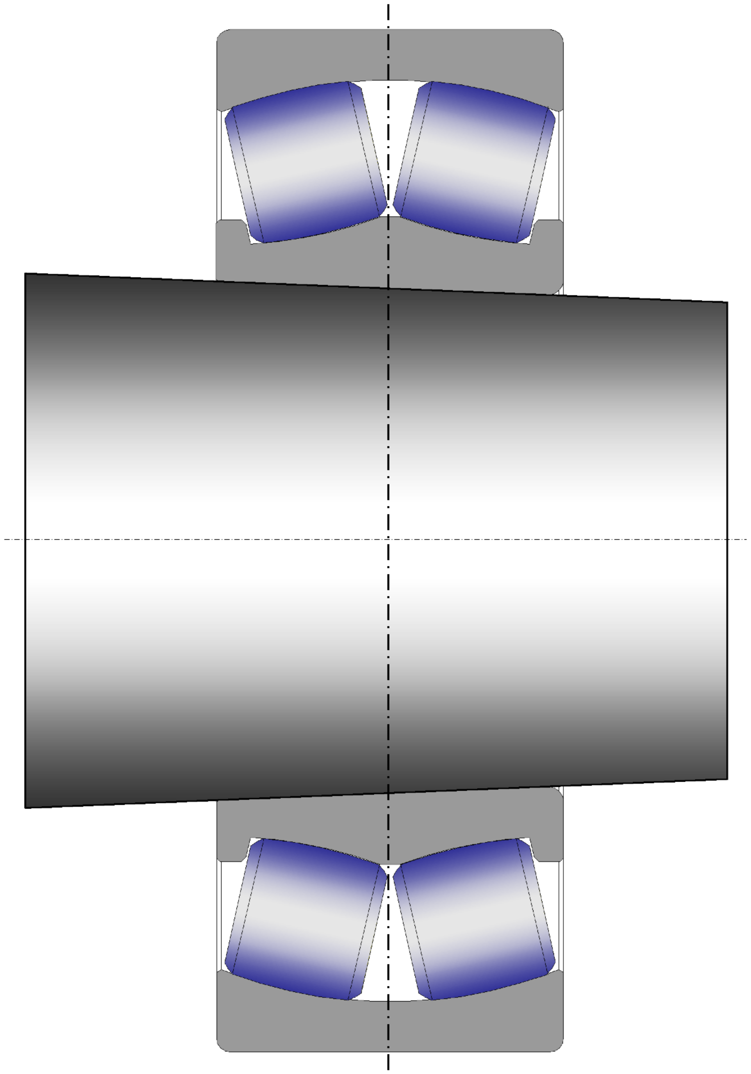



Effect of Oversize Roller on Bearing Life
22310 w/ 0.001 in IRC at 5000 lb, 1800 rpm
Bearing Life, hour
11,400
11,200
11,000
10,800
10,600
10,400
10,200
0.000000
0.000025
0.000050
0.000075
0.000100
Oversize Amount, in

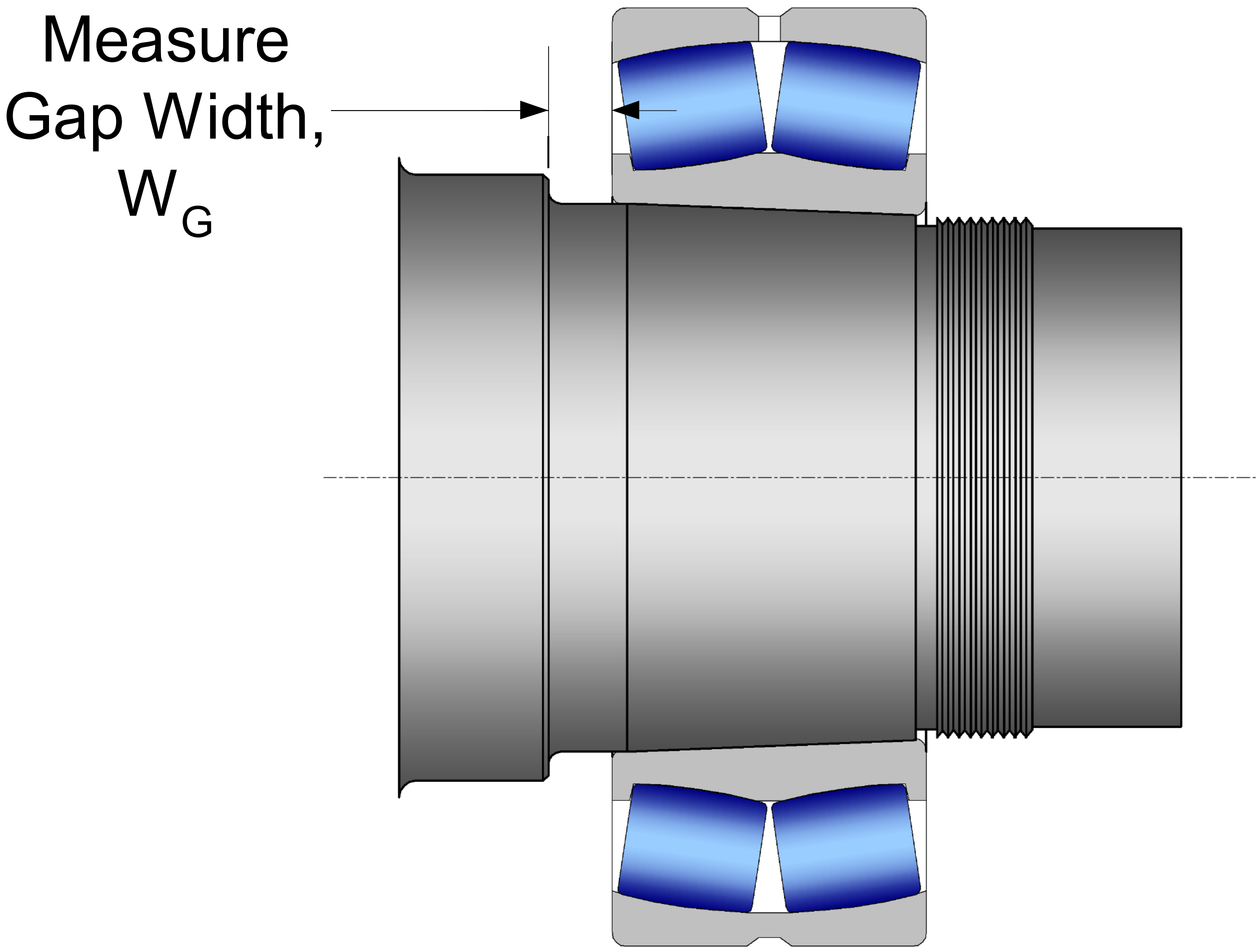
Preload Method



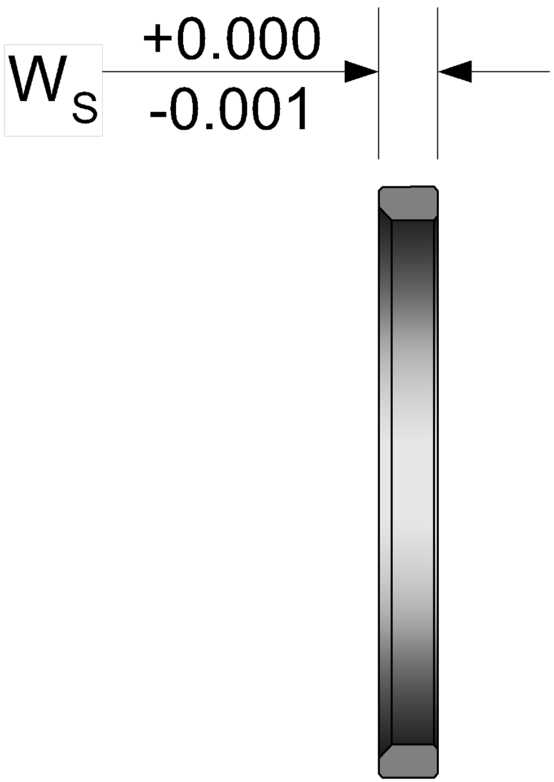
Preload Method



Mounting a Preloaded Spherical Roller Bearing

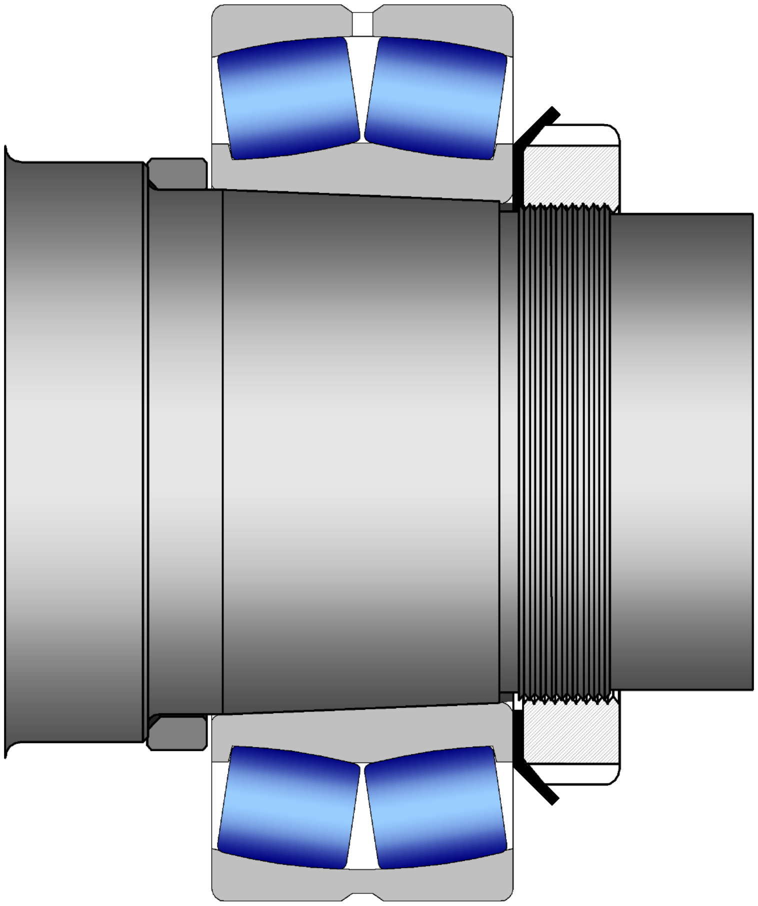


Mounting a Preloaded Spherical Roller Bearing - Spacer

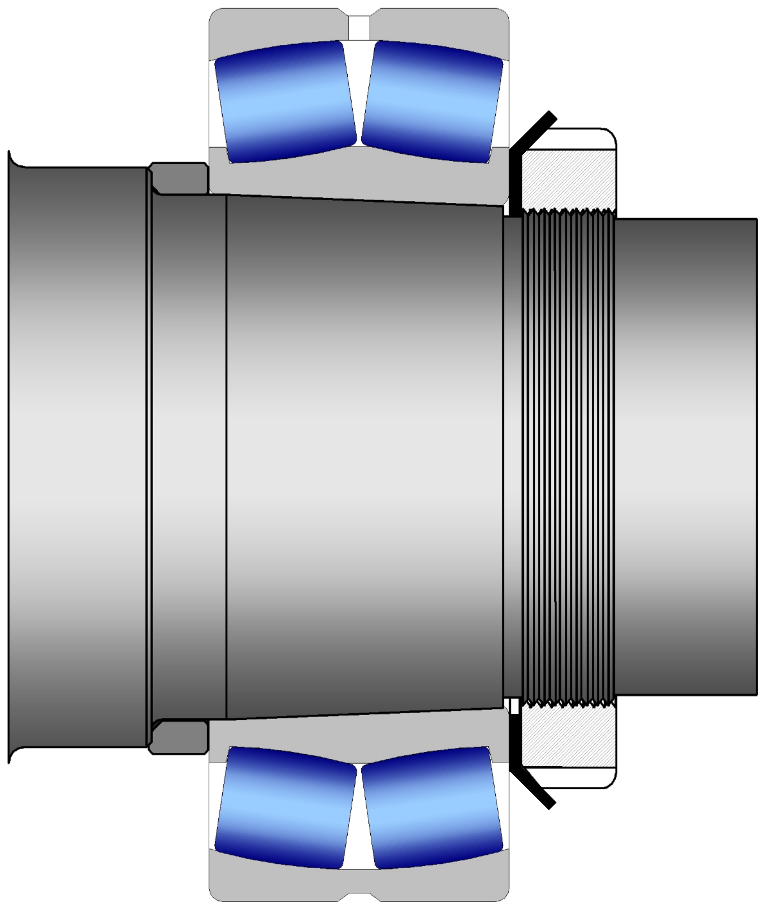


$W_S = W_G$ - Desired Take-Up

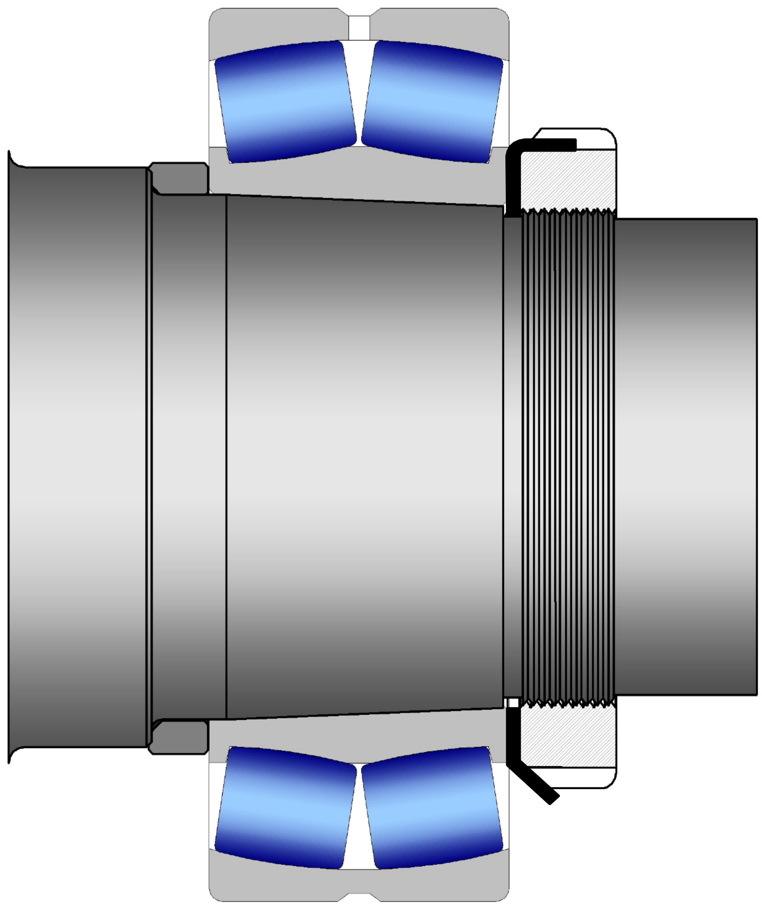
Mounting a Preloaded Spherical Roller Bearing



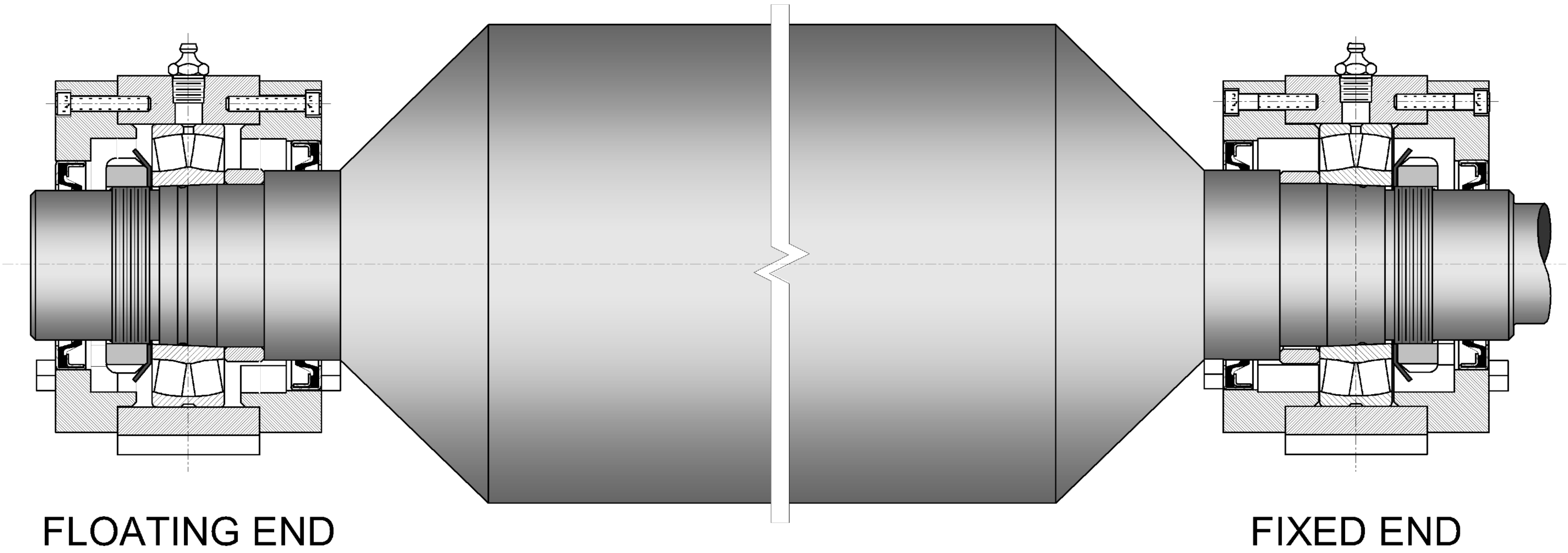
Mounting a Preloaded Spherical Roller Bearing



Mounting a Preloaded Spherical Roller Bearing



Typical Bearing Arrangement



Fit Analysis

DESCRIPTION OF ANALYSIS:	**22317K Sample** **Recommended Fits: Shaft, 0.0001T / 0.0018T; Housing, .0000 / .0010L**

BEARING DATA:

	SHAFT	I/R	R/E	CAGE	O/R	HSG	α
I. D., in	0.000	3.34650		4.750	6.33200	7.08710	12.42
O. D., in	3.34650	4.26800	1.05910	5.750	7.08660	8.000	**OR Osc**
Width, in		2.3622	0.9488	2.000	2.3622		98.52%
Raceway Dia., in		4.27			6.34		**IR Osc**
No. of Ribs or R/E		2	14		2		95.51%
Effective I/R O.D., O/R I.D.		4.268			6.334		**Roller Rad**
Material	4140	52100	52100	AMS4616	52100	1020	3.1961
Material Sp Wt, lb/cu in	0.283	0.283	0.283	0.31	0.283	0.283	
Print Fit	0.00000 T				0.00050 L		
Print Internal Radial Clearance (IRC)	0.00080	Take-up	0.0210	Pitch Dia	5.3020		

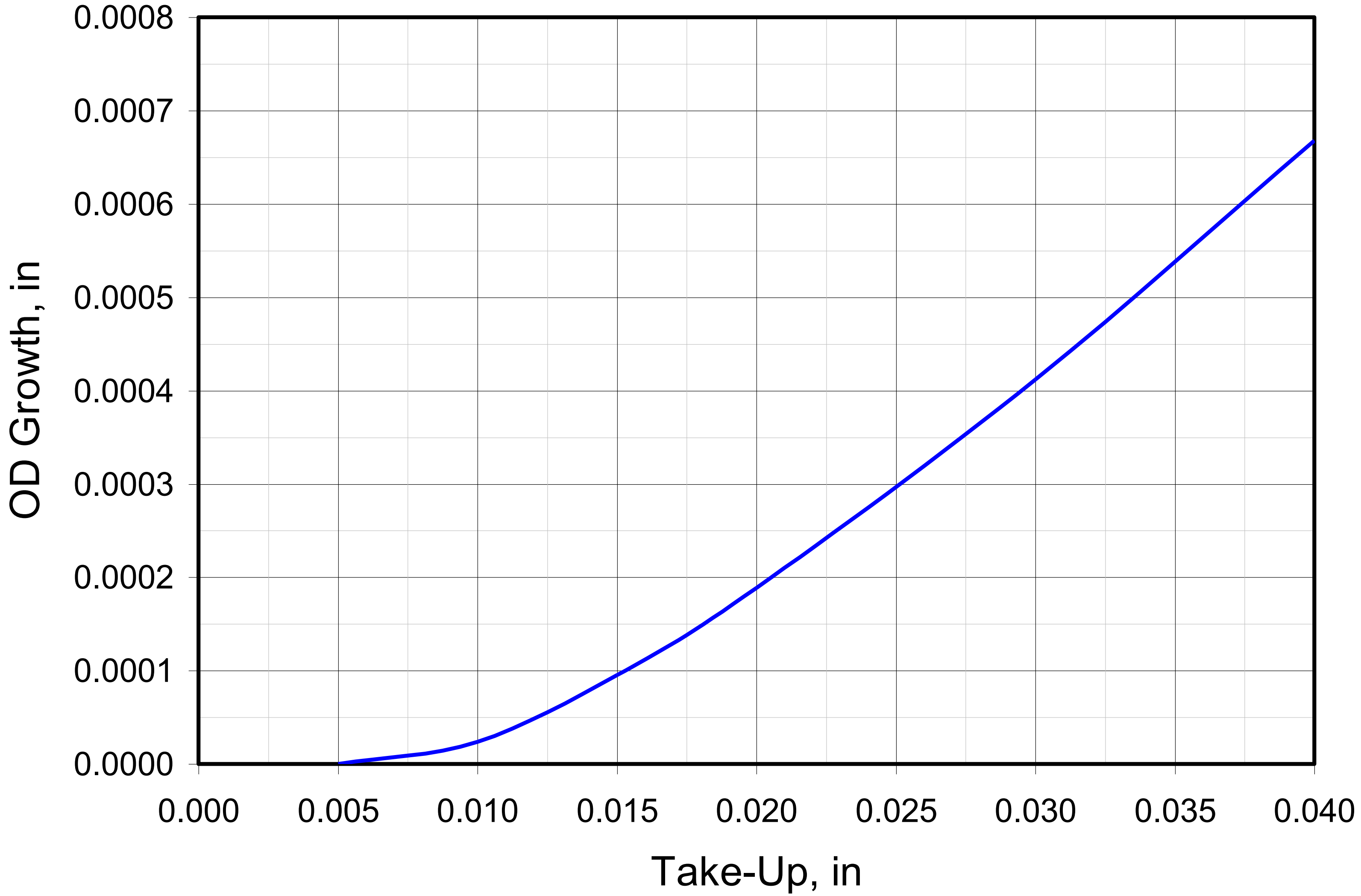
APPLICATION DATA:

		Roll Working Temperature, ºF					
		R/T	100	125	150	175	200
ITEM	**UNITS**	**VALUE**					
SHAFT SPEED	rpm	0	0	25	25	25	25
HOUSING SPEED	rpm	0	0	0	0	0	0
SHAFT TEMPERATURE	°F	70	100	125	150	175	200
INNER RING TEMPERATURE	°F	70	100	125	150	175	200
ROLLER TEMPERATURE	°F	70	100	125	150	175	200
CAGE TEMPERATURE	°F	70	100	125	150	175	200
OUTER RING TEMPERATURE	°F	70	100	125	150	175	200
HOUSING TEMPERATURE	°F	70	100	125	150	175	200

SUMMARY OF RESULTS

TOTAL INNER RACEWAY GROWTH	in	0.0013	0.0021	0.0028	0.0035	0.0042	0.0050
TOTAL ROLLER DIAMETER GROWTH	in	0.0000	0.0002	0.0004	0.0005	0.0007	0.0009
TOTAL OUTER RACEWAY GROWTH	in	0.0000	0.0012	0.0022	0.0032	0.0042	0.0052
NET CHANGE IN IRC	in	-0.0013	-0.0013	-0.0014	-0.0014	-0.0014	-0.0015
BEARING PRINT IRC	in	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
OPERATING IRC	in	-0.0005	-0.0005	-0.0006	-0.0006	-0.0006	-0.0007
INNER RING/SHAFT FIT	in	0.0017	0.0017	0.0017	0.0017	0.0017	0.0018
INTERFACE PRESSURE	ksi	2.85	2.87	2.90	2.92	2.94	3.07
HOOP STRESS	ksi	11.9	12.0	12.1	12.2	12.3	12.9
OUTER RING/HOUSING FIT	in	-0.0005	-0.0005	-0.0005	-0.0005	-0.0006	-0.0010
INTERFACE PRESSURE	ksi	0.00	0.00	0.00	0.00	0.00	0.00

Example of Bearing OD Growth as Effected by Take-Up



Sample Computer Analysis - Summary

Bearing Data

Bearing Size	22312
Bore, in	2.3622
O. D., in	4.7244
Width, in	1.6929
Pitch Dia., d_m, in	3.813
Roller Dia., D, in	0.7598
Roller Length, l, in	0.7323
Roller Effective Length, l_{eff}, in	0.6693
Contact Angle, α, °	13.25
No. of Rollers per Row, Z	14
No. of Rows of Rollers, I	2
Roller Race Radius, R_r, in	2.3039
Outer Race Radius, R_o, in	2.3385
Inner Race Radius, R_i, in	2.4122
I/R Roughness, μin AA	6
O/R Roughness, μin AA	10
Roller Roughness, μin AA	4

Application Data

Radial Load, F_r, lb	5807
Axial Load, F_a, lb	0
Inner Ring Speed, rpm	1,000
Outer Ring Speed, rpm	0
I/R Temperature, °F	100
O/R Temperature, °F	100
Oil temperature, °F	100
P_d, in	0
Reliability, %	90 (L10)

Caution: IRC is low

Materials

Inner Ring	52100CVD
Outer Ring	52100CVD
Roller	52100CVD
Lubricant	MOBIL SHC 220 GREASE

Results Summary	Inner Ring	Outer Ring
σ_{max}, ksi	-231	-155
Reliability Factor	1.00	1.00
Material Factor	3.0	3.0
Film Thickness, μin	7.73	8.31
Lube Film Factor	0.34	0.22
Row 1 L_{10} Life, hr	76,423	370,071
Row 2 L_{10} Life, hr	76,423	370,071
Row 1 L_{na} Life, hr	79,056	243,062
Row 2 L_{na} Life, hr	79,056	243,062
Bearing L_{10}, hr	35,907	
Bearing L_{na}, hr	34,218	
DN x 10^{-3}	60	
Cage Speed, rpm	403	
Roller Centrifugal Force, lb		0.8
Bearing Deflection, in	Radial	Axial
	0.0010	0.0000

Sample Computer Analysis - Row 1

δ_r	δ_a	L_0	x_0	y_0	x_1	x_2	Calc F_r	Calc F_a	Resid F_r	Resid F_a
0.001045	0.000000	3.9910	0.914734	3.884737	0.914734	0.914734	5,807	0	0.000	0.000

Row 1							2,903	834	Inner Race				Outer Race			
j	ϕ_j	$\delta_r \cos\phi$	y_1	L_1	δ_j	Q_j	$Q_j \cdot \cos\alpha \cdot \cos\phi_j$	$Q_j \cdot \sin\alpha$	b	a	$\frac{2a}{l_{eff}}$	σ_{max}	b	a	$\frac{2a}{l_{eff}}$	σ_{max}
1	0.000	0.001045	3.885782	3.9920	0.001017	932	907	214	0.0089	0.2175	0.65	-231	0.0088	0.3263	0.98	-155
2	25.714	0.000941	3.885678	3.9919	0.000916	797	699	183	0.0084	0.2064	0.62	-219	0.0084	0.3097	0.93	-147
3	51.429	0.000651	3.885389	3.9916	0.000634	459	278	105	0.0070	0.1717	0.51	-182	0.0070	0.2577	0.77	-122
4	77.143	0.000232	3.884970	3.9912	0.000226	98	21	22	0.0042	0.1026	0.31	-109	0.0042	0.1539	0.46	-73
5	102.857	-0.000232	3.884505	3.9908	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
6	128.571	-0.000651	3.884086	3.9903	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
7	154.286	-0.000941	3.883796	3.9901	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
8	180.000	-0.001045	3.883693	3.9900	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
9	205.714	-0.000941	3.883796	3.9901	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
10	231.429	-0.000651	3.884086	3.9903	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
11	257.143	-0.000232	3.884505	3.9908	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
12	282.857	0.000232	3.884970	3.9912	0.000226	98	21	22	0.0042	0.1026	0.31	-109	0.0042	0.1539	0.46	-73
13	308.571	0.000651	3.885389	3.9916	0.000634	459	278	105	0.0070	0.1717	0.51	-182	0.0070	0.2577	0.77	-122
14	334.286	0.000941	3.885678	3.9919	0.000916	797	699	183	0.0084	0.2064	0.62	-219	0.0084	0.3097	0.93	-147

Sample Computer Analysis - Row 2

δ_r	δ_a	L_0	x_0	y_0	x_1	x_2	Calc F_r	Calc F_a	Resid F_r	Resid F_a
0.001045	0.000000	3.9910	0.914734	3.884737	0.914734	0.914734	5,807	0	0.000	0.000

Row 2							2,903	834	Inner Race				Outer Race			
j	ϕ_j	$\delta_r\cos\phi$	y_2	L_2	δ_j	Q_j	$Q_j \cdot \cos\alpha \cdot \cos\phi_j$	$Q_j \cdot \sin\alpha$	b	a	$\frac{2a}{l_{eff}}$	σ_{max}	b	a	$\frac{2a}{l_{eff}}$	σ_{max}
1	0.000	0.001045	3.885782	3.9920	0.001017	932	907	214	0.0089	0.2175	0.65	-231	0.0088	0.3263	0.98	-155
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3	51.429	0.000651	3.885389	3.9916	0.000634	459	278	105	0.0070	0.1717	0.51	-182	0.0070	0.2577	0.77	-122
4	77.143	0.000232	3.884970	3.9912	0.000226	98	21	22	0.0042	0.1026	0.31	-109	0.0042	0.1539	0.46	-73
5	102.857	-0.000232	3.884505	3.9908	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
6	128.571	-0.000651	3.884086	3.9903	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
7	154.286	-0.000941	3.883796	3.9901	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
8	180.000	-0.001045	3.883693	3.9900	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
9	205.714	-0.000941	3.883796	3.9901	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
10	231.429	-0.000651	3.884086	3.9903	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
11	257.143	-0.000232	3.884505	3.9908	0.000000	0	0	0	0.0000	0.0000	0.00	0	0.0000	0.0000	0.00	0
12	282.857	0.000232	3.884970	3.9912	0.000226	98	21	22	0.0042	0.1026	0.31	-109	0.0042	0.1539	0.46	-73
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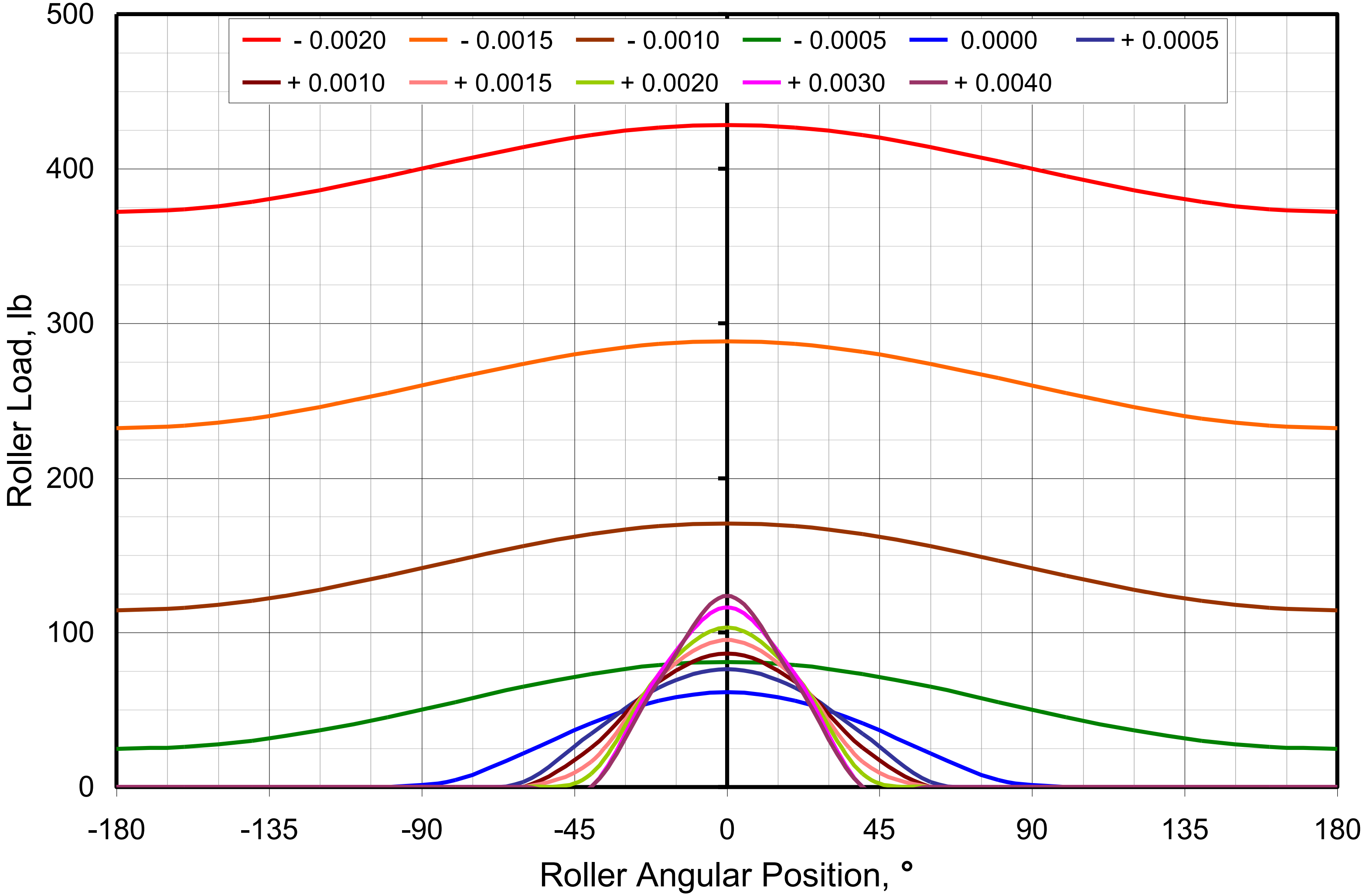
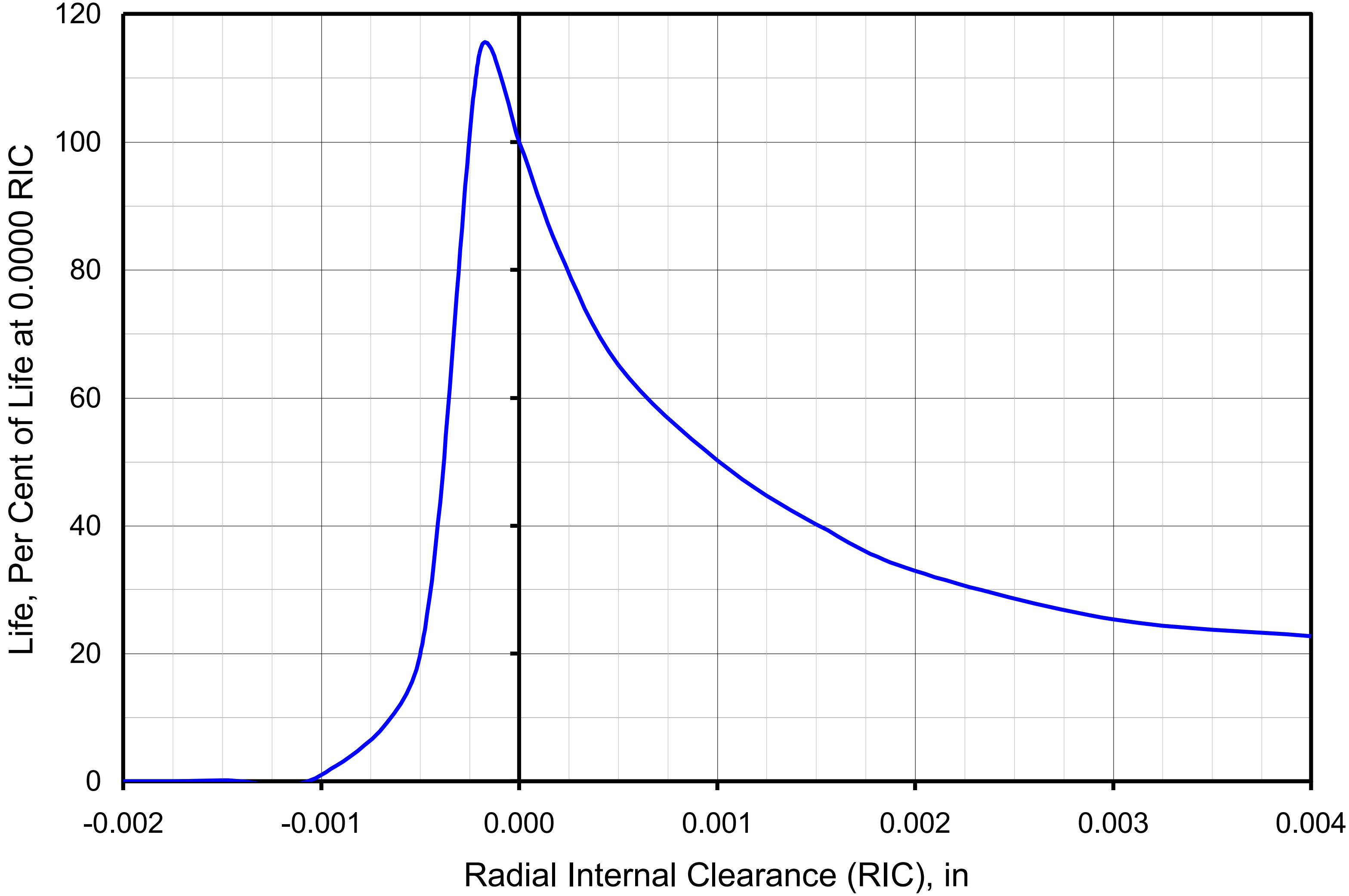
14	334.286	0.000941	3.885678	3.9919	0.000916	797	699	183	0.0084	0.2064	0.62	-219	0.0084	0.3097	0.93	-147

Effect of Radial Internal Clearance on Roller Load Distribution



Effect of Radial Internal Clearance on Bearing Life



Lubrication

- Prolongs Fatigue Life
- Minimizes Friction & Wear
- Inhibits Corrosion
- Dissipates Heat
- Excludes Contaminates

Lubricant Types

- Fluid
  - Oil
  - Grease
- Solid
- Gas

Application Methods for Oil

- Static (Oil Bath)
- Circulating
- Mist
- Film

Application Methods for Grease

- Sealed for Life
- Repack
- Grease Gun
- Self Powered Units
- Automatic Systems

Lubrication Filtration

Fatigue-life results of 65 mm bore ball bearing tests for various levels of filtration in a contaminated lubricant

Test series[a]	Test filter absolute rating, μ	Experimental hours: 10-per-cent life, L_{10}	Experimental hours: 50-per-cent life, L_{50}	Weibull slope	Failure index[b]	Confidence number,[c] percent: 10-per-cent life	Confidence number,[c] percent: 50-per-cent life
I	49	672	2276	1.54	9 out of 32	—	—
II	3	505	993	2.78	10 out of 16	63	99
III	30	594	857	5.12	11 out of 16	57	99
IV	49	367	533	5.06	20 out of 32	89	99
[d]V	105	—	—	—	—	—	—

[a] Test series I used clean oil, in all others contaminants were added.
[b] Number of fatigue failures out of number of bearings tested.
[c] Probability expressed as a percentage that the fatigue life in the contaminated lubricant test series will be less than the life with the clean oil in test series I.
[d] Test series V was suspended after 448 test hours on each of the test bearings due to excessive bearing wear. No fatigue failures were encountered.

Test bearings average weight loss

Test series[a]	Test filter absolute rating, μ	Suspended test bearings: gm/brg	Suspended test bearings: gm/100 hr	Failed test bearings: gm/brg	Failed test bearings: gm/100 hr
I	49	0.0412	0.0031	0.2775	0.0311
II	3	.0548	.0059	.3157	.0390
III	30	.0806	.0100	.1679	.0214
IV	49	.0809	.0130	.3288	.0713
[b]V	105	1.0204	.2757	—	—

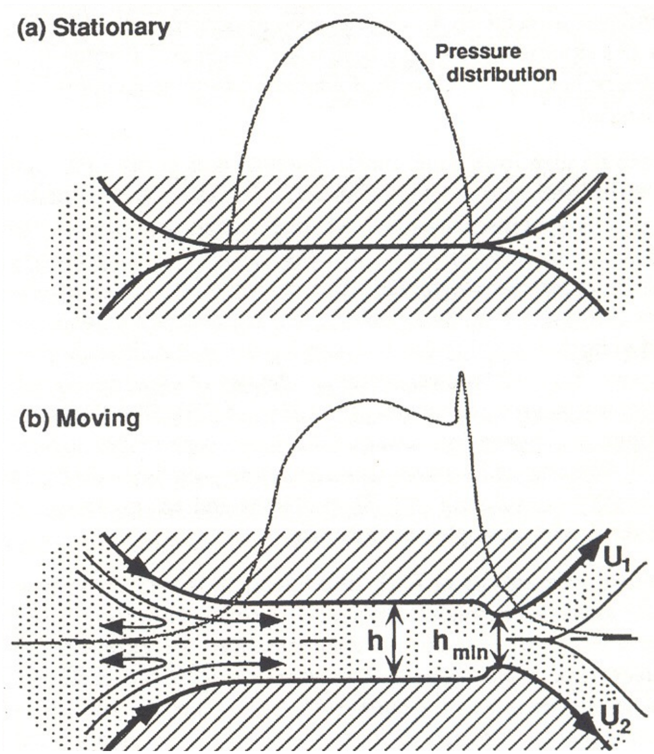
[a] Test series I used clean oil, in all others contaminants were added.
[b] All bearings from test series V suspended due to heavy wear.

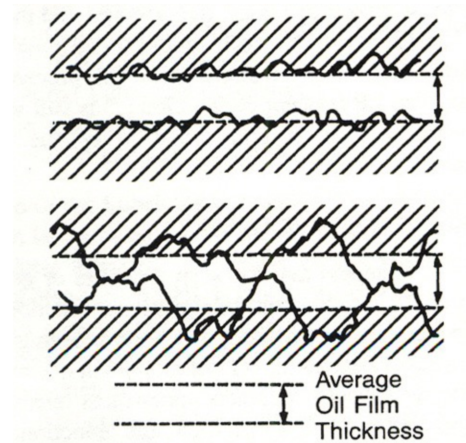
Elastohydrodynamic Lubrication

- Rheology
- Pressure Viscosity Relationship
- Elastic Deformation

$$h \propto \frac{\alpha^{0.6}\,\eta_0^{0.7}\,N^{0.7}}{P^{0.13}}$$

Elastohydrodynamic Lubrication





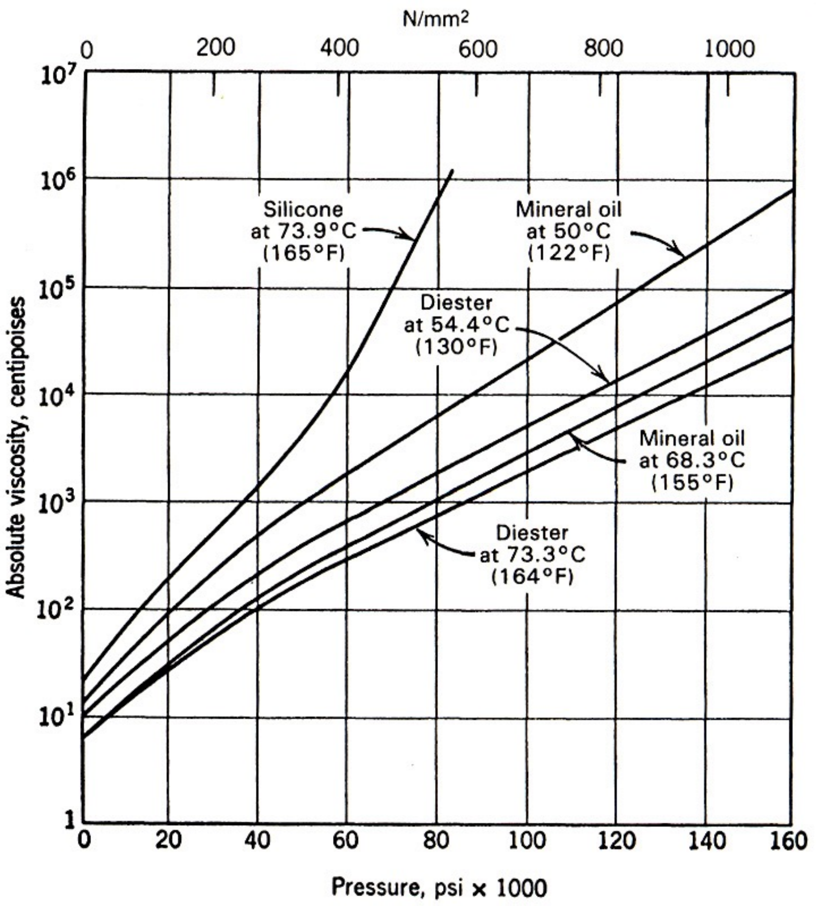
σ = Composite Roughness, μ-in, rms (R_q)

= $[\sigma_1^2 + \sigma_2^2]^{1/2}$

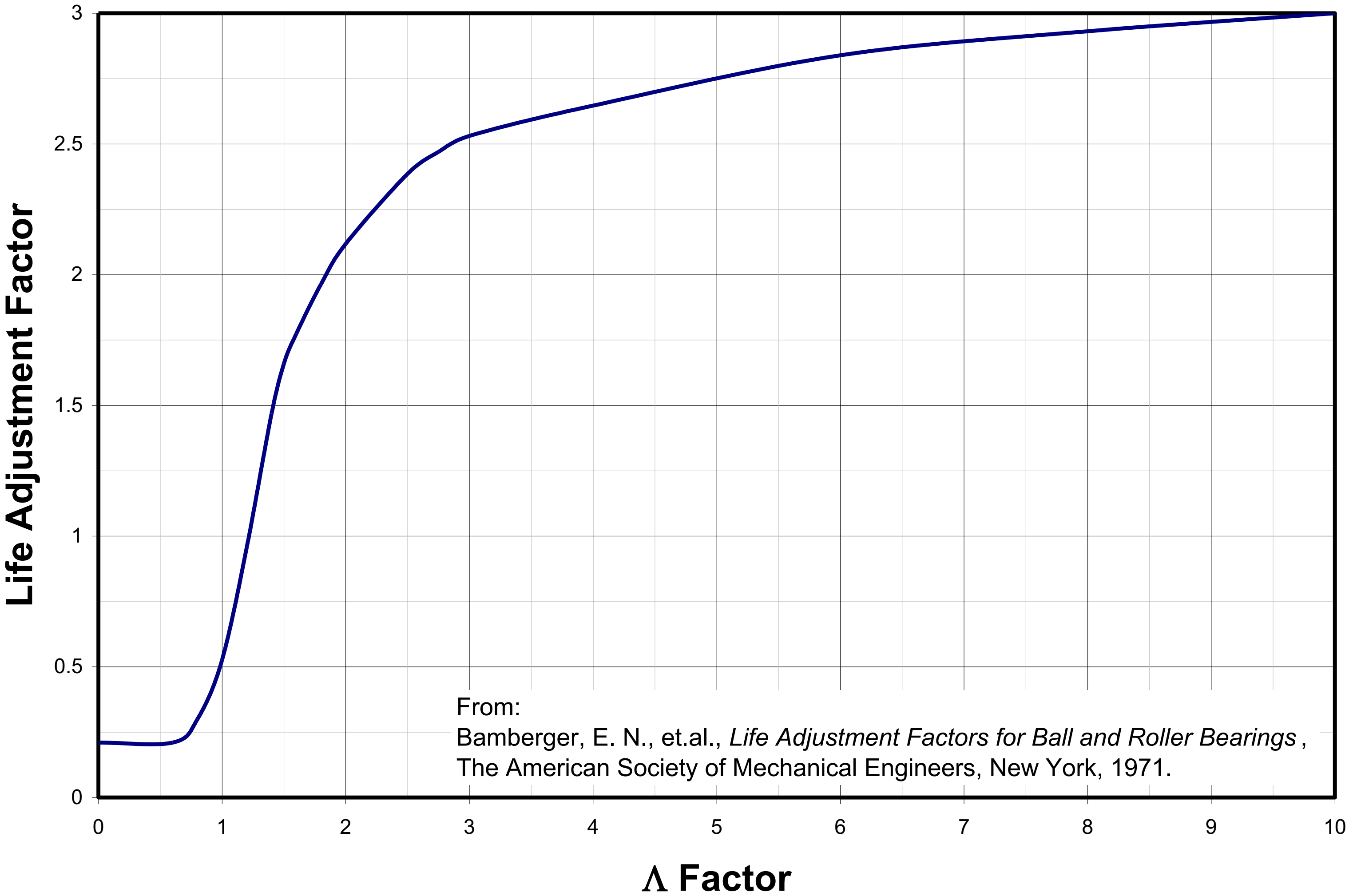
h = Film Thickness

Λ = h/σ

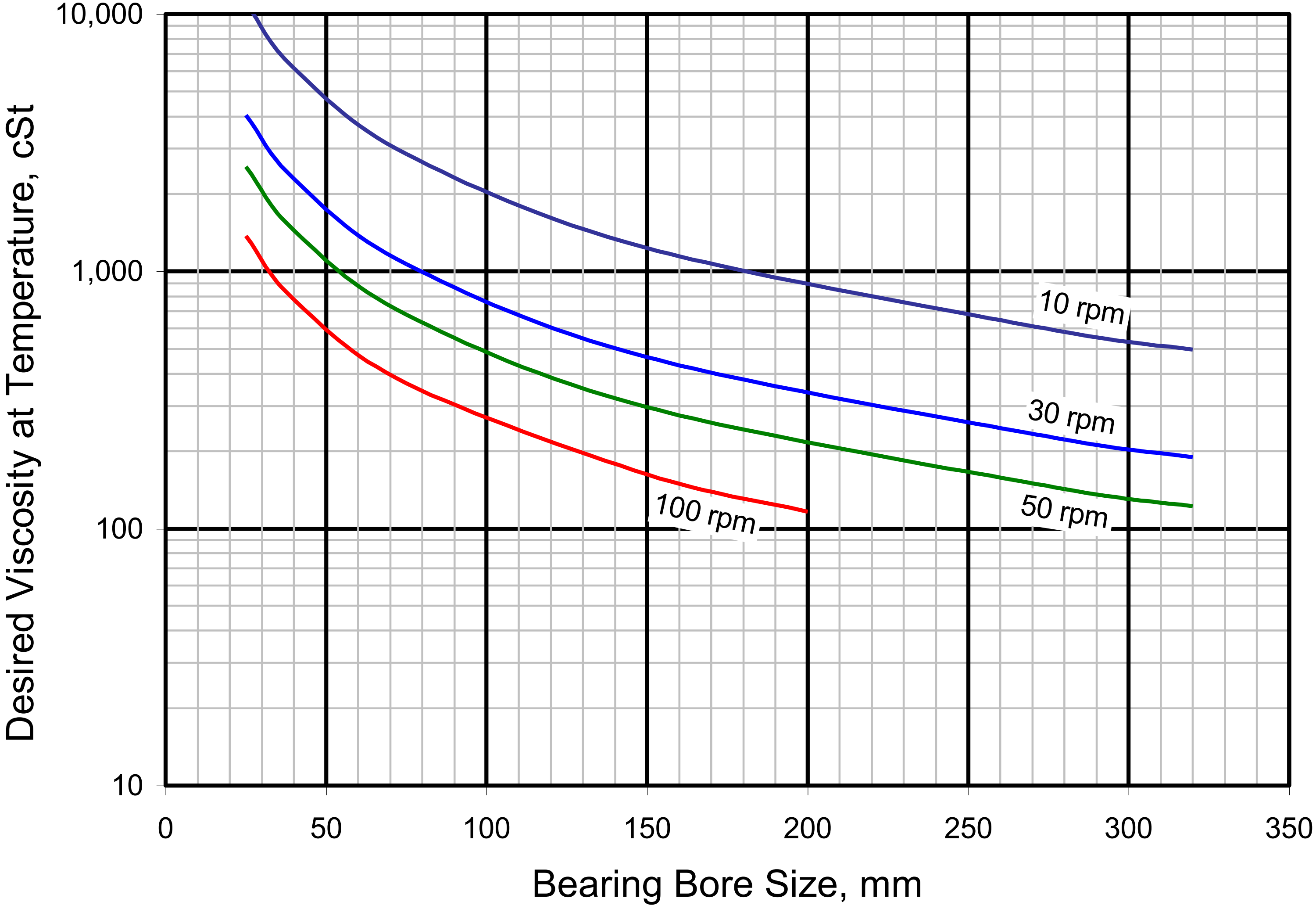
Pressure - Viscosity Chart



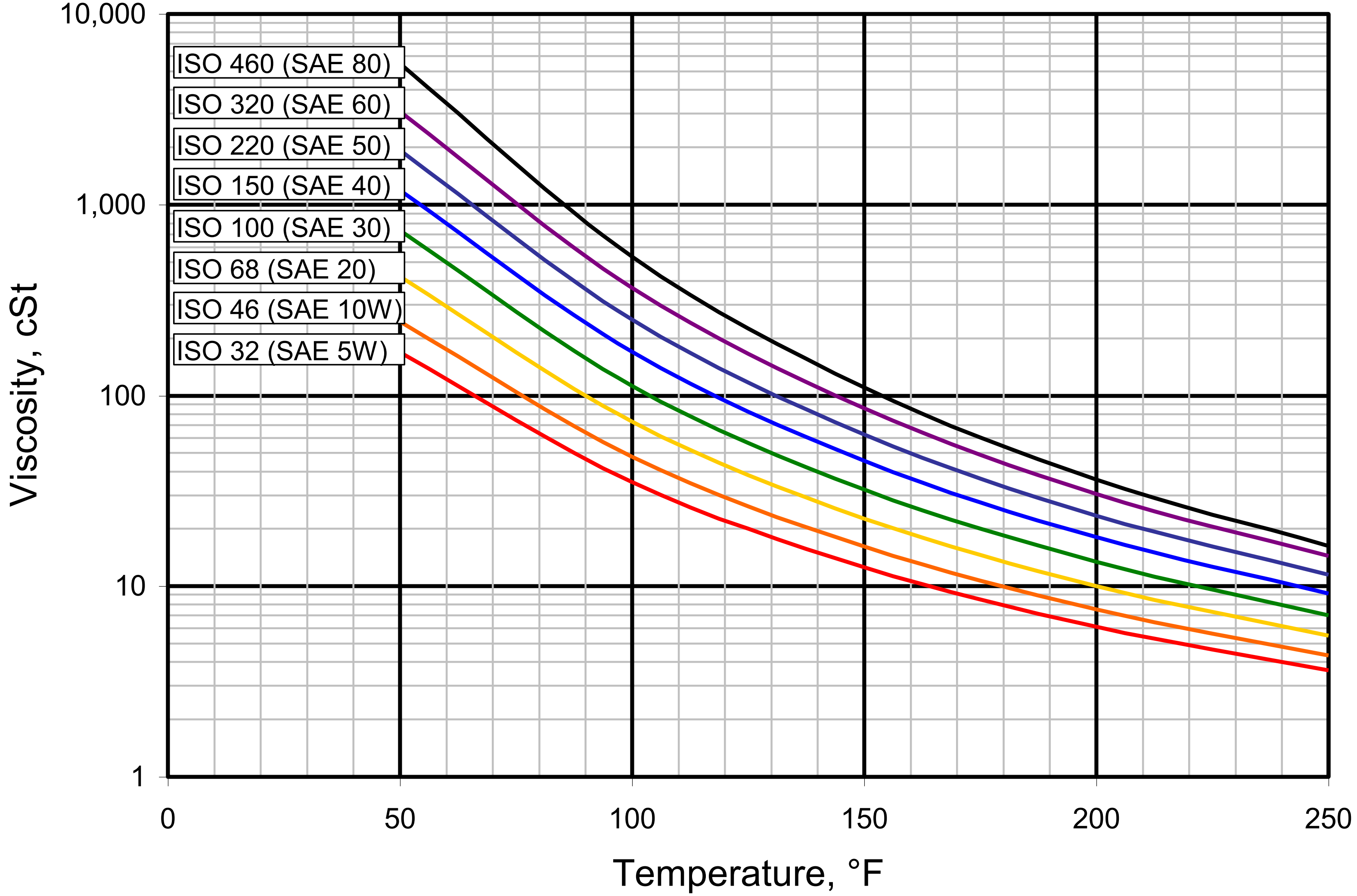
Film Thickness Effect on Bearing Life



Required viscosity to preclude life reduction for spherical roller bearings



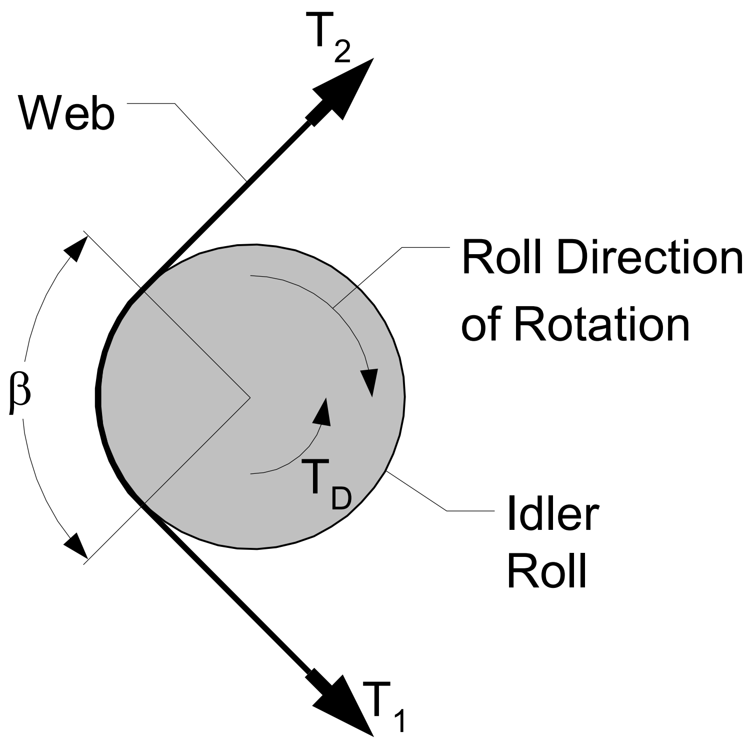
Variation in viscosity with temperature for mineral oils with VI~100



Mobilith SHC Series Greases (Exxon-Mobil)

Mobilith SHC Series	100	220	460	007	1500
NLGI Grade	2	2	1.5	0	1
Thickener Type	Lithium complex	Lithium complex	Lithium complex	Lithium complex	Lithium complex
Color, Visual	Red	Red	Red	Red	Red
Penetration, Worked, 25º C, ASTM D 217	280	280	305	415	325
Dropping Point, ºC, ASTM D 2265	255	255	255	NA	255
Viscosity of Oil, ASTM D 445 cSt @ 40º C	100	220	460	460	1370
Timken OK Load, ASTM D 2509, lb.	--	50	70	70	--
4-Ball Weld, ASTM D 2596, Load, Kg	250	250	250	--	250
Water Washout, ASTM D 1264, Loss at 79º C. % wt	6	4	3	--	2
Rust Protection, ASTM D 6138	0	0	0	--	0
USSteel Mobility @ -18º C	--	6	5	27	4

Web Slippage



T_1 = Upstream Web Tension, pli

T_2 = Downstream Web Tension, pli

$T_2 \geq T_1$

T_D = Roll Total Drag Torque, lb·in

$= T_R + T_I$

T_R = Roll running torque at constant speed, lb·in

T_I = Roll Inertia torque due to acceleration at start, lb·in

D = Roll Diameter, in

w = Web Width, in

β = Angle of Wrap

μ = Friction Coefficient

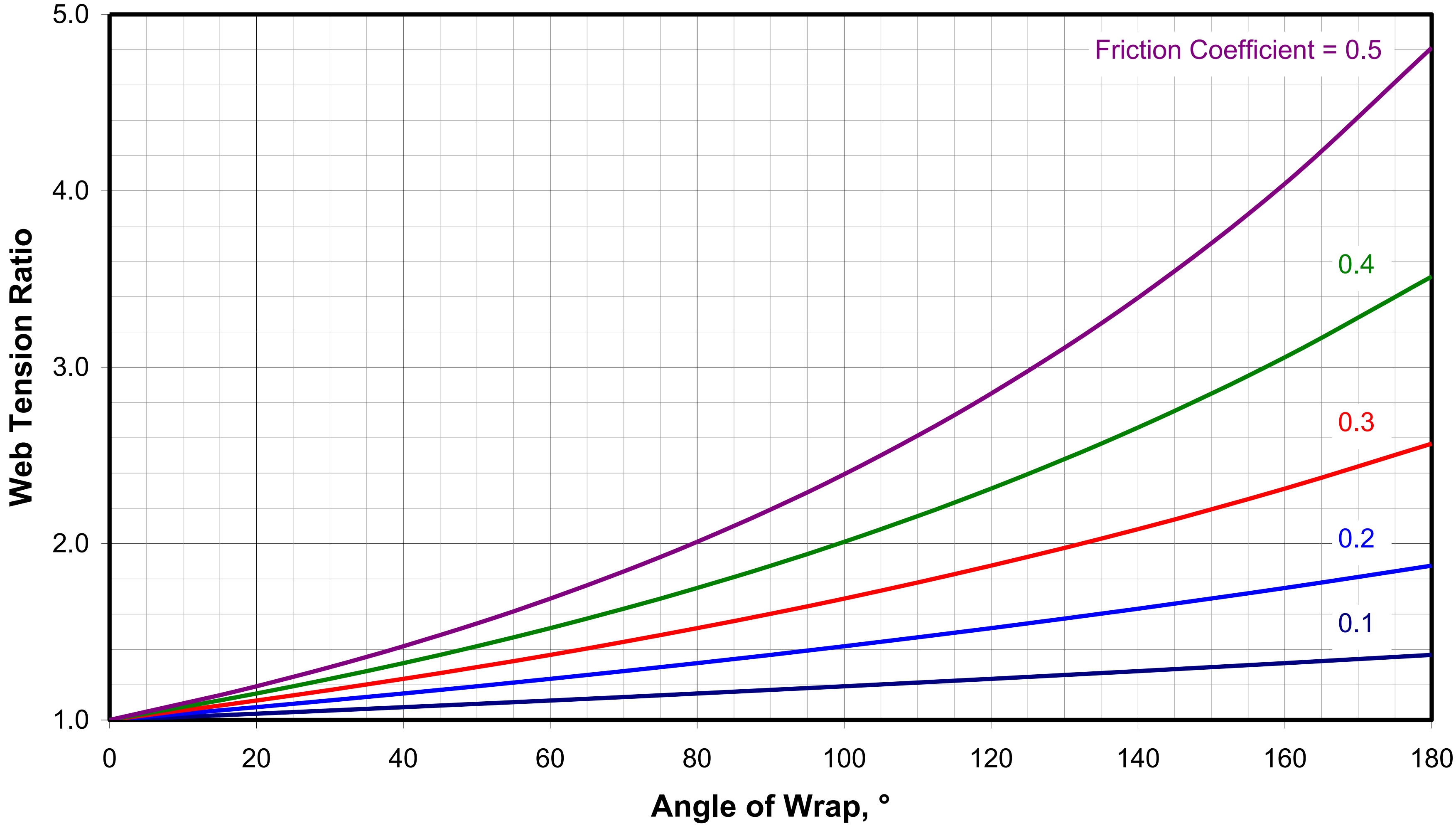
The relationship between T_1 and T_2 is as follows:

$$\frac{T_2}{T_1} \leq e^{\beta\mu} \qquad (1)$$

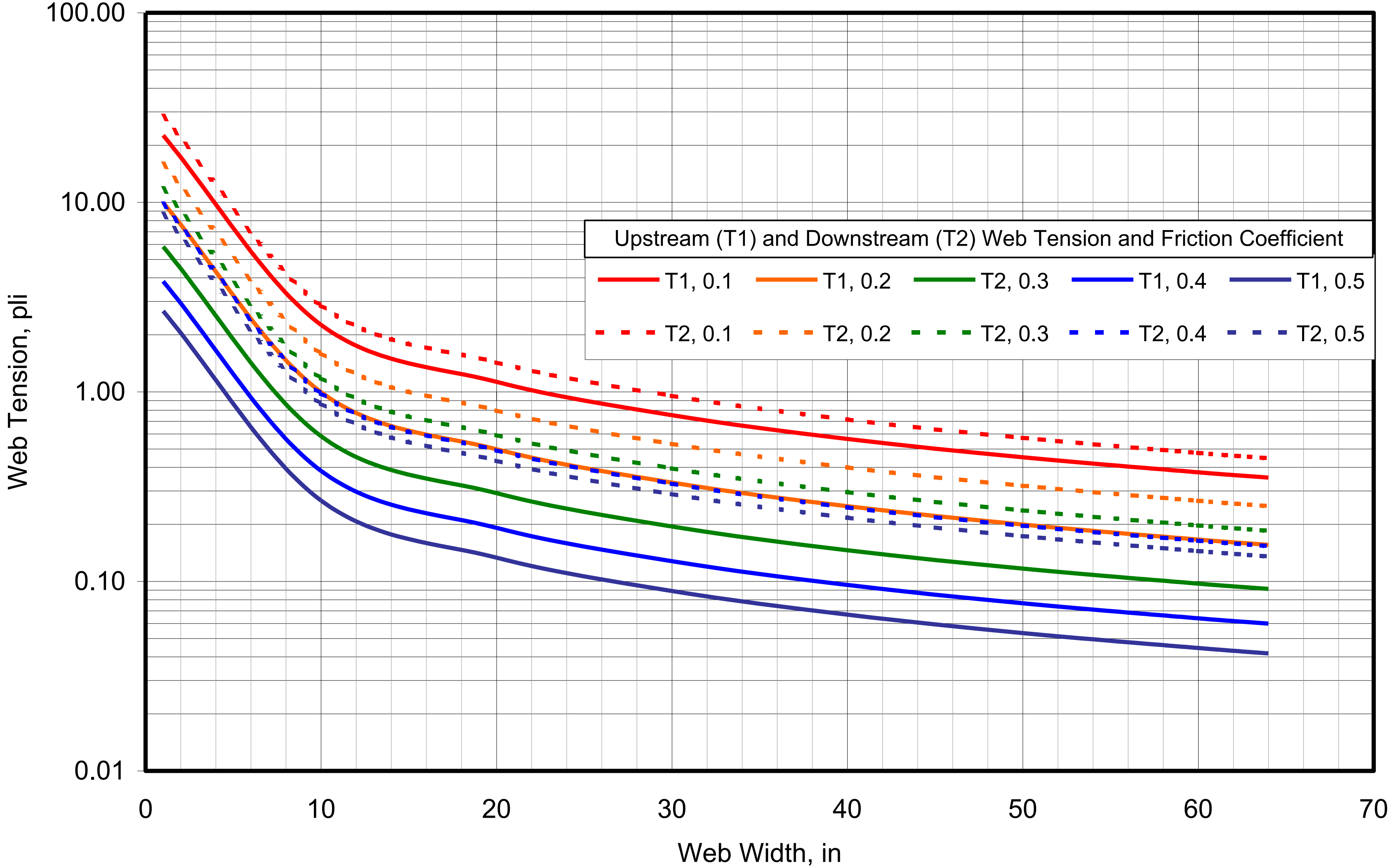
For the web to drive the idler roll without slippage, the following relationship must hold:

$$\tfrac{1}{2}(T_2 - T_1)wD \geq T_D \qquad (2)$$

Maximum Web Tension Ratio as a Function of Angle of Wrap and Friction Coefficient

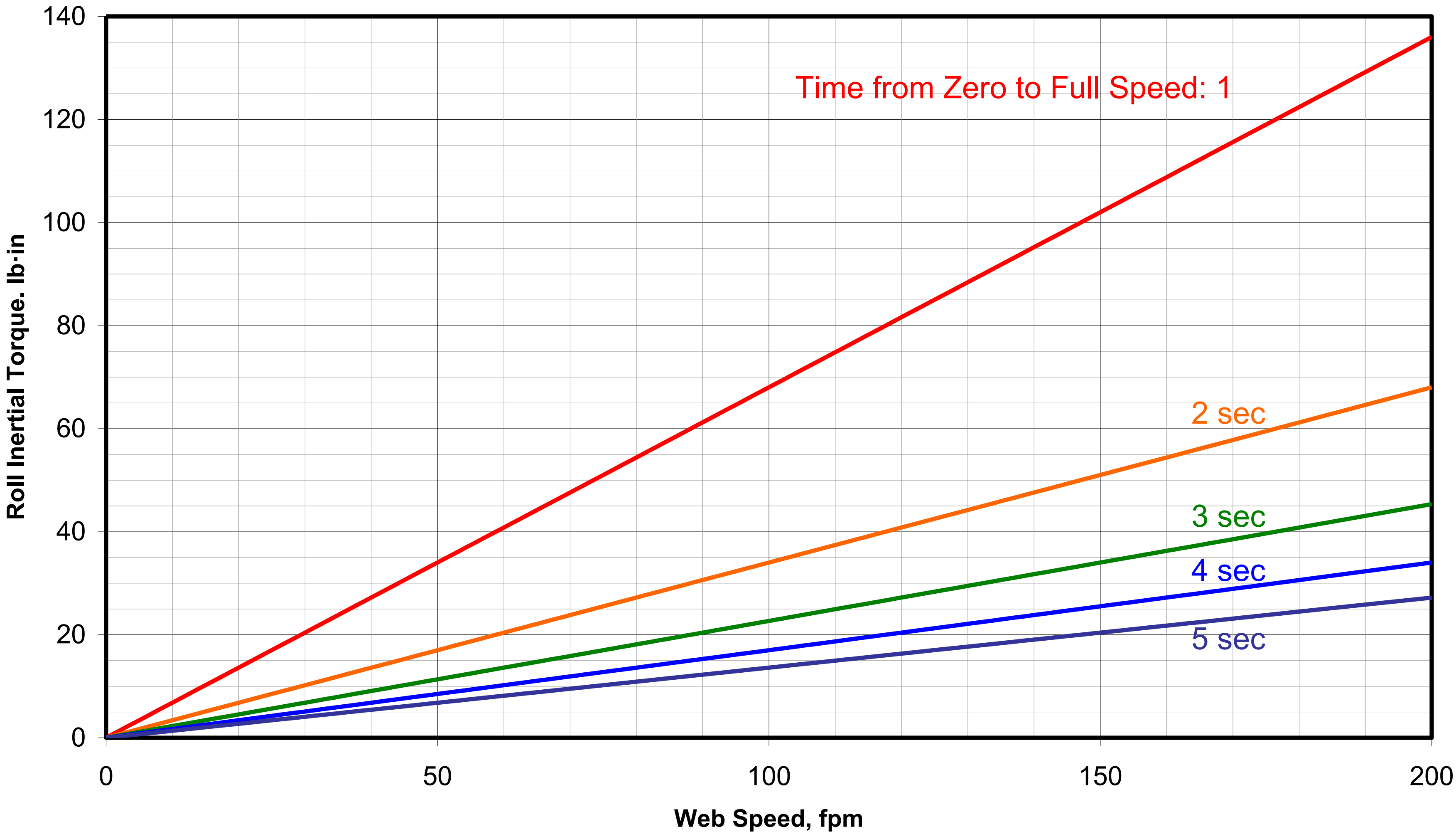


Required Web Tension to Drive Idler Roll at Constant Speed
Drag Torque = 30 lb·in, Roll Diameter = 10", Angle of Wrap = 135°



CPB ***Custom Precision Bearings, Inc.***

Inertial Torque at Start-Up for a Roll
Roll Diameter = 10", Polar Moment of Inertia = 17.0 lb·in·sec^2



Web Slippage

Example:

$\beta = 135°$

$= 2.356$ radian

$w = 60$ in

$D = 10$ in

$\mu = 0.2$ (e.g., polyester)

$T_2 / T_1 \leq e^{(2.356)(0.2)}$

≤ 1.602

$T_2 \leq 1.602(T_1)$

To avoid slippage,

$T_D \leq ½(T_2 - T_1)wD$

$\leq ½(1.602-1)T_1(60)(10)$

$\leq 180.6T_1$

$T_1 \geq T_D/180.6$

If

$T_D = T_R$ (Constant Speed)

$= 30$ lb·in

$T_1 \geq 30/180.6$

≥ 0.17 pli

$T_2 \geq 1.602(0.17)$

≥ 0.27 pli

At start-up, assume it is desired to reach full speed of 200 fpm in 2 seconds:

$T_I = 68$ lb·in

$T_D = T_R + T_I$

$= 1.5x30+68$

$= 113$ lb·in

$T_1 \geq 113/180.6$

≥ 0.62 pli

$T_2 \geq 1.602(0.54)$

≥ 1.00 pli

Chill Roll Assembly