his means that for a load of P = 143 lbs. the rating life of this ball bearing will be one million revoluions and 90% of a group of such ball bearings will be expected to complete or exceed this value.

Suppose now it is desired to determine the "L_{10}" life of this bearing when operating at 200 RPM md a load of 50 Ibs, the life being evaluated in hours of operation.

Let the life in hours be denoted by and let N denote the RPM of the bearing. We then have

$$l_{10} = \frac{10^6 L_{10}}{60N} = \left(\frac{C}{P}\right)^3 \frac{10^6}{60N} \qquad (29)$$

Substituting N = 200, P = 50 and C = 143 into Equation (29) we obtain l_{10} = 1949 hours.

NOTE: L_{10} is bearing life in millions of revolutions l_{10} is bearing life in hours.

A chart showing required life at constant operating speed has been given by N. Chironis ("Today's Ball Bearings", Product Engineering, December 12, 1960, pp. 63-77, chart on p. 68). This chart is hereby reproduced with the permission of McGraw-Hill Book Company, New York, N.Y.

(d) Combined Axial and Radial Loads

Such cases can be evaluated according to the methods previously outlined by combining the axial and radial loads into an equivalent radial load. This is defined in ANSI/AFBMA Standard 9,1978 as follows:

"Calculation of Equivalent Radial Load. The magnitude of the equivalent radial load P, for radial and angular contact bearings, under combined constant radial and constant thrust loads, is:

$$P = XF_r + YF_a$$

Values of X and V are given in Table 4.

The rating and sizing of ball bearings involve many considerations, many of which are beyond the scope of this introductory presentation. For further information the reader is referred to the technical literature.

6.0 TOLERANCES AND CLEARANCES

For satisfactory operation of a ball bearing, suitable shaft and housing tolerances are extremely important. Standard tolerance ranges have been established by the industry and Tables 5 and 6 show recommended deviations of shaft diameters and housing bores from nominal.

For normal conditions the recommendations of many manufacturers for rotating shafts and stationary housings, as given by Wilcock and Booser, recommend fits in the approximate range K5 and J6 for shaft fits, and J6 and H7 for housing fits.

A fuller discussion of tolerances and their relation to bearing applications, installation and design is a complex subject beyond the scope of this presentation. This would include considerations involving temperature effects, high-speed operation, shock loading, lubrication, environmental conditions etc. For a discussion of such topics the reader is referred to the technical literature.

"Bearing Design and Application" by D.F. Wilcock and ER. Booser, McGraw Hill, New York. N.Y., 1st Ed., 1957, p.69

TABLE 2* VALUES OF f_c

$D \cos \alpha$ / d_m	Single Row Radial Contact; Single & Double Row Angular Contact, Groove Type(1)		Double Row Radial Contact Groove Type		Self Aligning	
	Metrict(2)	lnch(3)	Metrict(2)	Inch(3)	Metric(2)	Inch(3)
0.05	46.7	3550	44.2	3360	17.3	1310
0.06	49.1	3730	46.5	3530	18.6	1420
0.07	51.1	3880	48.4	3680	19.9	1510
0.08	52.8	4020	50.0	3810	21.1	1600
0.09	54.3	4130	51.4	3900	22.3	1690
0.10	55.5	4220	52.6	4000	23.4	1770
0.12	57.5	4370	54.5	4140	25.6	1940
0.14	58.8	4470	55.7	4230	27.7	2100
0.16	59.8	4550	56.5	4290	29.7	2260
0.18	59.9	4530	56.8	4310	31.7	2410
0.20	59.9	4550	56.8	4310	33.5	2550
0.22	59.6	4530	56.5	4290	35.2	2680
0.24	59.0	4480	55.9	4250	36.8	2790
0.26	58.2	4420	55.1	4190	38.2	2910
0.28	57.1	4340	54.1	4110	39.4	3000
0.30	56.0	4250	53.0	4030	40.3	3060
0.32	54.6	4160	51.8	3950	40.9	3110
0.34	53.2	4050	50.4	3840	41.2	3130
0.36	51.7	3930	48.9	3730	41.3	3140
0.38	50.0	3800	47.4	3610	41.0	3110
0.40	48.4	3670	45.8	3480	40.4	3070

(1) a. When calculating the basic load rating for a unit consisting of two similar, single row, radial contact ball bearings,In a duplex mounting, the pair is considered as one, double row, radial contact ball bearing.

b. When calculating the basic load rating for a unit consisting of two, similar, single row, angular contact ball bearings in a duplex mounting, “Face-to-Face” or “Back-to-Back”, the pair Is considered as one, double row, angular contact ball bearing.

c. When calculating the basic load rating for a unit consisting of two or more similar, single angular contact ball bearings mounted “in Tandem”, properly manufactured and mounted for equal load distribution, the rating of the combination is the number of bearings to the 0.7 power times the rating of a single row bell bearing. If the unit may be treated as a number of individually interchangeable single row bearings, this footnote 1c does not apply.

(2)Use to obtain C in newtons when 0 is given in mm.
(3)Use to obtain C in pounds when D is given in inches.

TABLE 3*

REQUIRED LIFE AT CONSTANT OPERATING SPEED (data from SKF Industries)	
Type of machine	Life in hours of operation
Instruments and apparatus which are only infrequently used Ex.: demonstration apparatus, devices for operation of sliding doors....	500
Aircraft engines	500—2000
Machines for service of short duration or intermittent operation, where service interruptions are of minor importance Ex: hand tools, lifting tackle In machinery shops, hand-driven machines in general, farm machinery, assembly cranes, charging machines, foun dry cranes, household machines	4000—8000
Machines for intermittent service where dependable operation is of great importance Ex: auxiliary machines in power stations, conveying-equipment in production lines, elevators, general-cargo cranes, machine tools less frequently used	8000—12,000
Machines for 8—hour service which are not always fully utilized Ex: machines in general in the mechanical industries, cranes for continuous service, blowers, jackshafts.....	20,000—30,000
Machines for continuous operation (24—hour service) Ex.: separators, compressors, pumps, main-line shafting, roller beds and conveyor rollers, mine hoists, stationary electric motors	40,000—60,000
Machines for 24—hour service where dependability is of great importance Ex.: pulp and paper machines, public power stations, mine pumps, public pumping stations, machines for continuous service aboard ship	100,000—200,000

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Reproduced from "Today's Ball Bearings" by N. Chironis, Product Engineering, December12, 1960, pp. 68 with the permission of McGraw-Hill Book Co. Inc., New York, N.Y.

TABLE 4* VALUES OF X AND Y

Bearing Type				Single Row Bearings		Double Row Bearings				
				$\frac{F_a}{F_r} > e$		$\frac{F_a}{F_r} \le e$		$\frac{F_a}{F_r} > e$		e
				X	Y	X	Y	X	Y	
Radial Contact Groove Ball Bearings	$\frac{F_a}{C_o}$	$\frac{F_a}{iZD^2}$ Units Newtons, mm	Units lbs. in							
	0.014	0.172	25		2.30				2.30	0.19
	0.028	0.345	50		1.99				1.99	0.22
	0.056	0.689	100		1.71				1.71	0.26
	0.084	1.03	150	0.56	1.58	1	0	0.56	1.55	0.28
	0.11	1.38	200		1.45				1.45	0.30
	0.17	2.07	300		1.31				1.31	0.34
	0.28	3.45	500		1.15				1.15	0.38
	0.42	5.17	750		1.04				1.04	0.42
	0.56	6.89	1000		1.00				1.00	0.44
Angular Contact Groove Ball Bearings with Contact Angle 5°	$\frac{iF_a}{C_o}$	$\frac{F_a}{ZD^2}$ Units Newtons, mm	Units lbs. in	For this type use the X, Y and e values applicable to single row radial contact bearings						
	0.014	0.172	25				2.78		3.74	0.23
	0.028	0.345	50				2.40		3.23	0.26
	0.056	0.689	100				2.07		2.78	0.30
	0.085	1.03	150			1	1.87	0.78	2.52	0.34
	0.11	1.38	200				1.75		2.36	0.36
	0.17	2.07	300				1.58		2.13	0.40
	0.28	3.45	500				1.39		1.87	0.45
	0.42	5.17	750				1.26		1.69	0.50
	0.56	6.89	1000				1.21		1.63	0.52
10°	0.014	0.172	25		1.88		2.18		3.06	0.29
	0.029	0.345	50		1.71		1.98		2.78	0.32
	0.057	0.689	100		1.52		1.76		2.47	0.36
	0.086	1.03	150		1.41		1.63		2.20	0.38
	0.11	1.38	200	0.46	1.34	1	1.55	0.75	2.18	0.40
	0.17	2.07	300		1.23		1.42		2.00	0.44
	0.29	3.45	500		1.10		1.27		1.79	0.49
	0.43	5.17	750		1.01		1.17		1.64	0.54
	0.57	6.89	1000		1.00		1.16		1.63	0.54
15°	0.015	0.172	25		1.47		1.65		2.39	0.38
	0.029	0.345	50		1.40		1.57		2.28	0.40
	0.058	0.689	100		1.30		1.46		2.11	0.43
	0.087	1.03	150		1.23		1.38		2.00	0.46
	0.12	1.38	200	0.44	1.19	1	1.34	0.72	1.93	0.47
	0.17	2.07	300		1.12		1.26		1.82	0.50
	0.29	3.45	500		1.02		1.14		1.66	0.55
	0.44	5.17	750		1.00		1.12		1.63	0.56
	0.58	6.89	1000		1.00		1.12		1.63	0.56
20°				0.43	1.00	1	1.09	0.70	1.63	0.57
25°				0.41	0.87	1	0.92	0.67	1.41	0.68
30°				0.39	0.76	1	0.78	0.63	1.24	0.80
35°				0.37	0.66	1	0.66	0.60	1.07	0.95
40°				0.35	0.57	1	0.55	0.57	0.96	1.14
Self-aligning Ball Bearings				0.40	0.4 cot α	1	0.42 cot α	0.65	0.65 cot α	1.5 tan α

(1) Two similar, single row, angular contact ball bearings mounted “Face-to-Face” or “Back-to-Back are considered as one, double row, angular contact bearing.

(2) Values of X. V and e for a toad or contact angle other than shown in Table 2 are obtained by linear interpolation.

(3) Values of X. V and a shown in Table 2 do not apply to filling slot bearings for applications in which ball-raceway contact areas protect substantially into tile tilling slot under load

(4) For single row bearinge when $F_a/F_r \leq e$, use X = 1, Y=0.

TABLE 5** DEVIATION OF SHAFT DIAMETERS FROM NOMINAL DIMENSIONS, IN.*

Fit inner ring to shaft		Push fit	Push fit to wringing fit	Wringing fit	Drive fit		Light force fit		Force fit		Heavy force fit	
Nominal diam mm		g6	h6	h5	js	j6	k5	k6	m5	m6	n6	p6
Over	Incl.											
3	6	−0.0002 −0.0005	0 −0.0003	0 −0.0002	+0.0002 −0.0000							
6	10	−0.0002 −0.0006	0 −0.0004	0 −0.0002	+0.0002 −0.0001	+0.0003 −0.0001						
10	18	−0.0002 −0.0007	0 −0.0004	0 −0.0003	+0.0002 −0.0001	+0.0003 −0.0001	+0.0004 +0.0000	+0.0006 +0.0000				
18	30	−0.0003 −0.0008	0 −0.0005	0 −0.0004	+0.0002 −0.0002	+0.0004 −0.0002	+0.0004 +0.0001	+0.0008 +0.0001	+0.0007 +0.0003	+0.0008 +0.0003	+0.0011 +0.0006	
30	50	−0.0004 −0.0010	0 −0.0006	0 −0.0004	+0.0002 −0.0002	+0.0004 −0.0002	+0.0005 +0.0001	+0.0007 +0.0001	+0.0008 +0.0004	+0.0010 +0.0004	+0.0013 +0.0007	+0.0017 +0.0010
50	80	−0.0004 −0.0011	0 −0.0007	0 −0.0005	+0.0002 −0.0003	+0.0005 −0.0003	+0.0006 +0.0001	+0.0008 +0.0001	+0.0009 +0.0004	+0.0012 +0.0004	+0.0015 +0.0008	+0.0020 +0.0013
80	120	−0.0005 −0.0013	0 −0.0009	0 −0.0006	+0.0002 −0.0004	+0.0005 −0.0004	+0.0007 +0.0001	+0.0010 +0.0001	+0.0011 +0.0005	+0.0014 +0.0005	+0.0018 +0.0009	+0.0023 +0.0015
120	180	−0.0006 −0.0015	0 −0.0010	0 −0.0007	+0.0003 −0.0004	+0.0006 −0.0004	+0.0008 −0.0001	+0.0011 +0.0001	+0.0013 +0.0006	+0.0016 +0.0006	+0.0020 +0.0011	+0.0027 +0.0017

* After SKF.

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TABLE 6** DEVIATION OF HOUSING BORES FROM NOMINAL DIMENSIONS, IN.*

Fit housing—outer ring		Close-running fit	Slide fit		Push fit		Wringing fit		Drive fit		Heavy drive fit		Light force fit	
Nominal diam, mm.		G7	H8	H7	J7	J6	K6	K7	M6	M7	N6	N7	P6	P7
Over	Incl.													
10	18	+0.0002 +0.0009	0 +0.0011	0 +0.0007	−0.0003 +0.0004	−0.0002 +0.0002	−0.0004 +0.0001	−0.0006 +0.0002	−0.0006 −0.0002	−0.0007 0	−0.0008 −0.0004	−0.0009 −0.0002	−0.0010 −0.0006	−0.0011 −0.0004
18	30	+0.0003 +0.0011	0 +0.0013	0 +0.0008	−0.0004 +0.0005	−0.0002 +0.0003	−0.0004 +0.0001	−0.0006 +0.0002	−0.0007 −0.0002	−0.0008 0	−0.0009 −0.0004	−0.0011 −0.0003	−0.0012 −0.0007	−0.0014 −0.0006
30	50	+0.0004 +0.0013	0 +0.0015	0 +0.0010	−0.0004 +0.0006	−0.0002 +0.0004	−0.0005 +0.0001	−0.0007 +0.0003	−0.0008 −0.0002	−0.0010 0	−0.0011 −0.0006	−0.0013 −0.0003	−0.0015 −0.0008	−0.0017 −0.0007
50	80	+0.0004 +0.0016	0 +0.0018	0 +0.0012	−0.0005 +0.0007	−0.0002 +0.0005	−0.0006 +0.0002	−0.0008 +0.0004	−0.0009 −0.0002	−0.0012 0	−0.0013 −0.0006	−0.0015 −0.0004	−0.0018 −0.0010	−0.0020 −0.0008
80	120	+0.0005 +0.0019	0 +0.0021	0 +0.0014	−0.0005 +0.0009	−0.0002 +0.0006	−0.0007 +0.0002	−0.0010 +0.0004	−0.0011 −0.0002	−0.0014 0	−0.0015 −0.0006	−0.0018 −0.0004	−0.0020 −0.0012	−0.0023 −0.0009
120	180	+0.0006 +0.0021	0 +0.0025	0 +0.0018	−0.0006 +0.0010	−0.0003 +0.0007	−0.0008 +0.0002	−0.0011 +0.0005	−0.0013 −0.0003	−0.0018 0	−0.0018 −0.0008	−0.0020 −0.0005	−0.0024 −0.0014	−0.0027 −0.0011
180	250	+0.0006 +0.0024	0 +0.0028	0 +0.0018	−0.0006 +0.0012	−0.0003 +0.0009	−0.0009 +0.0002	−0.0013 +0.0005	−0.0015 −0.0003	−0.0018 0	−0.0020 −0.0009	−0.0024 −0.0006	−0.0026 −0.0016	−0.0031 −0.0013
250	315	+0.0007 +0.0027	0 +0.0032	0 +0.0020	−0.0006 +0.0014	−0.0003 +0.0010	−0.0011 +0.0002	−0.0014 +0.0006	−0.0016 −0.0004	−0.0020 0	−0.0022 −0.0010	−0.0026 −0.0008	−0.0031 −0.0019	−0.0035 −0.0014
315	400	+0.0007 +0.0030	0 +0.0035	0 +0.0022	−0.0007 +0.0015	−0.0003 +0.0011	−0.0011 +0.0003	−0.0016 +0.0007	−0.0018 −0.0004	−0.0022 0	−0.0024 −0.0010	−0.0029 −0.0006	−0.0034 −0.0020	−0.0039 −0.0016
400	500	+0.0008 +0.0033	0 +0.0038	0 +0.0025	−0.0008 +0.0017	−0.0003 +0.0013	−0.0013 +0.0003	−0.0018 +0.0007	−0.0020 −0.0004	−0.0025 0	−0.0026 −0.0011	−0.0031 −0.0007	−0.0037 −0.0022	−0.0043 −0.0018
500	630	+0.0009 +0.0035	0 +0.0041	0 +0.0027	−0.0009 +0.0018	−0.0003 +0.0014	−0.0014 +0.0003	−0.0019 +0.0008	−0.0022 −0.0005	−0.0027 0	−0.0029 −0.0012	−0.0034 −0.0007	−0.0041 −0.0024	−0.0046 −0.0020

* After SKF.

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