Bearing Lubrication

Lubrication is essential to prevent premature ball bearing failure. Probably the most critical factor in maintaining operating conditions, the lubricant functions to:

1) minimize friction between balls and raceways,
2) act as a preventative against rust and corrosion,
3) dissipate heat build-up, and
4) provide a barrier against the entry of foreign matter.

The type of lubricant used also plays a critical factor in operating efficiency. Conventional types fall into the classifications of oil or grease, each with specific properties correct for different bearing applications. Generally, grease is the preferred choice due to its ease of application and maintenance, performing well in the 0°F to 300°F operating range. Oil, however, does function better in extreme temperature conditions, below -40°F or above 350°F.

The following chart recommends the ten key lubricants used by General Bearing Corporation.

CHARACTERISTICS OF GREASE LUBRICANTS USED IN GENERAL BEARING PRODUCTS

COMPANY TRADEMARK	MIL SPEC	BASE OIL	THICKENER	OPERATING RANGE	CHARACTERISTICS
Dow Corning DC41		Silicon	Carbon	-0° to 550°F	Worked penetration of 280. Excellent for high temperature requirements.
DuPont Krytox 240AC	MIL-G-27617A	Fluorocarbon	Uidax	-30° to 550°F	Worked penetration of 295. Excellent for both high and low temperature applications.
Exxon Beacon 325	MIL-G-3278	Diester	Lithium	-65° to 250°F	Excellent for low temperature applications.
Exxon Polyrex EM		Mineral	Polyurea	-20° to 350°F	Long performance life. Excellent for high speeds and high temperature.
Kyodo Yushi Multemp SB-M		Synthetic Hydrocarbon	Diurea	-40° to 400°F	Long performance life. Excellent for high and low temperature applications.
Kyodo Yushi Multemp SRL		Synthetic Hydrocarbon	Lithium	-40° to 300°F	Long performance life. Excellent for high and low temperature applications.
Mobil 28	MIL-PRF-81322F	Synthetic Hydrocarbon	Clay Bentonite	-65° to 350°F	Excellent for high and low temperature applications.
Shell Aeroshell 7	MIL-G-23827B	Diester	Microgel	-100° to 300°F	Worked penetration of 288. Excellent for low temperature lubrication qualities.
Shell Alvania 2	MIL-G-18709	Mineral	Lithium	-20° to 250°F	Worked penetration of 287. General purpose lubrication.

Shaft and Housing Fits

FOR METRIC RADIAL BALL AND ROLLER BEARINGS

To select the proper fits, it is necessary to consider the type and extent of the load, bearing type, and certain other design and performance requirements.

The required shaft and housing fits are indicated in Tables 1 and 3. The terms "Light", "Normal" and "Heavy" loads refer to radial loads that are generally within the following limits (C being the Basic Dynamic Load Rating computed in accordance with ABMA-ANSI Standards).

Radial Load	Ball Bearings	Roller Bearings
Light	up to 0.07C	up to 0.08C
Normal	from 0.07C to 0.15C	from 0.08C to 0.18C
Heavy	over 0.15C	over 0.18C

Shaft Fits. Table 1 indicates the initial approach to shaft fit selection. Note that for most normal applications where the shaft rotates and the radial load direction is constant, an interference fit should be used. Also, the heavier the load, the greater is the required interference. For stationary shaft conditions and constant radial load direction, the inner ring may be moderately loose on the shaft.

Note that for pure thrust (axial) loading, heavy interference fits are not necessary as a moderately loose to tight shaft fit only is needed.

Table 2 shows how the tolerance ranges of the various classifications deviate from the basic bore diameters.

Housing Fits. Table 3 indicates the initial approach to housing fit selection. Note that the use of clearance or interference fits is mainly dependent upon which bearing ring rotates in relation to the radial load. For indeterminate or varying load directions, avoid clearance fits. Clearance fits are preferred in axially split housings to avoid distorting bearing outer rings. The extent of the radial load also influences the choice of fit.

Table 4 shows how the tolerance ranges of the various classifications deviate from the basic outside diameters.

Example:
Bearing No. 6203 (17mm x 40mm x 12mm).
Application: Electric motor (shaft and bearing inner ring rotating).
Load 20 lbs. radial
Per catalog Page 5: Basic Dynamic Load Rating (c) = 2153 lbs.

$$\frac{\text{Load}}{\text{c}} = \frac{\text{20 lbs.}}{\text{2153 lbs.}} = .009$$

Radial load is less than .07 of Dynamic Load rating (c); therefore, load is "light".

Table 1: Inner ring rotating, light radial load, 17 mm inner diameter: Tolerance classification should be h5.

Table 2: 17mm inner diameter (.6693") and h5 tolerance: Shaft diameter tolerance is +0", –.0003". Shaft diameter should be .6693" max., .6690" min.

Table 3: Outer ring stationary, light load, housing not split axially: Tolerance classification should be H6.

Table 4: 40mm outer diameter (1.5748") and H6 tolerance: Housing bore diameter tolerance is +0", +.0006". Housing bore diameter should be 1.5754" max., 1.5748" min.

TABLE 1 – SELECTION OF SHAFT TOLERANCE CLASSIFICATIONS

For Metric Radial Ball and Roller Bearings of Tolerance Classes ABEC-1, RBEC-1

DESIGN & OPERATING CONDITIONS			BALL BEARINGS					CYLINDRICAL ROLLER BEARINGS					SPHERICAL ROLLER BEARINGS				
Rotational Conditions	Inner Ring Axial Displaceability	Radial Loading	BORE d mm Over	mm Incl.	inch Over	inch Incl.	Tolerance Classification[1]	BORE d mm Over	mm Incl.	inch Over	inch Incl.	Tolerance Classification[1]	BORE d mm Over	mm Incl.	inch Over	inch Incl.	Tolerance Classification[1]
								0	40	0	1.57	j6[2]	0	40	0	1.57	j6[2]
			0	18	0	0.71	h5	40	140	1.57	5.51	k6[2]	40	100	1.57	3.94	k6[2]
		Light	18	All	0.71	All	j6[2]	140	320	5.51	12.6	m6[2]	100	320	3.94	12.6	m6[2]
								320	500	12.6	19.7	n6	320	500	12.6	19.7	n6
Inner Ring								500	All	19.7	All	p6	500	All	19.7	All	p6
Rotating								0	40	0	1.57	k5	0	40	0	1.57	k5
in relation								40	100	1.57	3.94	m5	40	65	1.57	2.56	m5
to load		Normal	0	18	0	0.71	j5	100	140	3.94	5.51	m6	65	100	2.56	3.94	m6
direction			18	All	0.71	All	k5	140	320	5.51	12.6	n6	100	140	3.94	5.51	n6
								320	500	12.6	19.7	p6	140	280	5.51	11.0	p6
or								500	All	19.7	All	r6	280	500	11.0	19.7	r6
													500	All	19.7	All	r7
Load								0	40	0	1.57	m5	0	40	0	1.57	m5
Direction			18	100	0.71	3.94	k5	40	65	1.57	2.56	m6	40	65	1.57	2.56	m6
indeter-		Heavy	100	All	3.94	All	m5	65	140	2.56	5.51	n6	65	100	2.56	3.94	n6
minate								140	200	5.51	7.87	p6	100	140	3.94	5.51	p6
								200	500	7.87	19.7	r6	140	200	5.51	7.87	r6
								500	All	19.7	All	r7	200	All	7.87	All	r7
Inner Ring Stationary	Inner Ring must be easily axially displaceable	Light / Normal / Heavy	All Sizes				g6	All Sizes				g6	All Sizes				g6
in relation to load direction	Inner Ring need not be easily axially displaceable	Light / Normal / Heavy	All Sizes				h6	All Sizes				h6	All Sizes				h6
Pure Thrust (Axial) Load			All Sizes				j6	Consult Bearing Manufacturer									

TABLE 2 – SHAFT DIAMETER TOLERANCE LIMITS

For Metric Radial Ball and Roller Bearings of Tolerance Classes ABEC-1, RBEC-1

Dimensions and deviations in inches and millimeters. Tolerance Limits in Inches.

BORE d inch Over	inch Incl.	inch Dev.	mm Over	mm Incl.	mm Dev.	g6	h6	h5	j5	j6	k5	k6	m5	m6	n6	p6	r6
0.1181		0	3		0	-.0002	0	0	+.0001	+.0002	+.0002		+.0004				
	0.2362	-.0003		6	-.008	-.0005	-.0003	-.0002	-.0001	-.0001	0		+.0002				
0.2362		0	6		0	-.0002	0	0	+.0002	+.0003	+.0003		+.0005				
	0.3937	-.0003		10	-.008	-.0006	-.0004	-.0002	-.0001	-.0001	0		+.0002				
0.3937		0	10		0	-.0002	0	0	+.0002	+.0003	+.0004		+.0006				
	0.7087	-.0003		18	-.008	-.0007	-.0004	-.0003	-.0001	-.0001	0		+.0003				
0.7087		0	18		0	-.0003	0		+.0002	+.0004	+.0004		+.0007				
	1.1811	-.0004		30	-.010	-.0008	-.0005		-.0002	-.0002	+.0001		+.0003				
1.1811		0	30		0	-.0004	0		+.0002	+.0004	+.0005	+.0007	+.0008	+.0010			
	1.9685	-.0045		50	-.014	-.0010	-.0006		-.0002	-.0002	+.0001	+.0001	+.0004	+.0004			
1.9685		0	50		0	-.0004	0		+.0002	+.0005	+.0006	+.0008	+.0009	+.0012	+.0015		
	3.1496	-.0006		80	-.015	-.0011	-.0007		-.0003	-.0003	+.0001	+.0001	+.0004	+.0004	+.0008		
3.1496		0	80		0	-.0005	0		+.0002	+.0005	+.0007	+.0010	+.0011	+.0014	+.0018	+.0023	
	4.7244	-.0008		120	-.020	-.0013	-.0009		-.0004	-.0004	+.0001	+.0001	+.0005	+.0005	+.0009	+.0015	
4.7244		0	120		0	-.0006	0		+.0003	+.0006	+.0008	+.0011	+.0013	+.0016	+.0020	+.0027	+.0035
	7.0866	-.0010		180	-.025	-.0015	-.0010		-.0004	-.0004	+.0001	+.0001	+.0006	+.0006	+.0011	+.0017	+.0026

[1] Tolerance classifications shown are for solid steel shafts. Numerical values are listed in Table 2. For hollow or non-ferrous shafts, tighter fits may be needed.

[2] If greater accuracy is needed, substitute j5, k5 and m5 for j6, k6 and m6 respectively.

TABLE 3 – SELECTION OF HOUSING TOLERANCE CLASSIFICATIONS

For Metric Radial Ball and Roller Bearings of Tolerance Classes ABEC-1, RBEC-1

DESIGN AND OPERATING CONDITIONS				TOLERANCE CLASSIFICATION[1]
Rotational Conditions	Loading	Other Conditions	Outer Ring Axial Displaceability	
Outer Ring Stationary in relation to load direction	Normal or Heavy	Heat input through shaft	Outer Ring easily axially displaceable	G7[3]
		Housing split axially		H7[2]
		Housing not split axially		H6[2]
	Shock with temporary complete unloading		Transitional Range[4]	J6[2]
Load Direction indeterminate	Light			
	Normal or Heavy	Split not recommended		K6[2]
	Heavy Shock			M6[2]
Outer Ring Rotating in relation to load direction	Light			
	Normal or Heavy		Outer Ring not easily axially displaceable	N6[2]
	Heavy	Thin wall housing not split		P6[2]

[1] For cast iron steel housings, numerical values are listed in Table 4. For housings of non-ferrous alloys tighter fits may be needed.
[2] Where wider tolerances are permissible, use tolerance classifications H8, H7, J7, K7, M7, N7 and P7 in place of H7, H6, J6, K6, M6, N6 and P6 respectively.
[3] For large bearings and temperature differences between outer ring and housings greater than 10°C, F7 may be used instead of G7.
[4] The tolerance zones are such that outer ring may be either tight or loose in the housing.

TABLE 4 – HOUSING BORE TOLERANCE LIMITS

For Metric Radial Ball and Roller Bearings of Tolerance Classes ABEC-1, RBEC-1

OUTER DIAMETER D						TOLERANCE CLASSIFICATIONS														
inch			mm																	
Over	Incl.	Dev.	Over	Incl.	Dev.	F7	G7	H8	H7	H6	J6	J7	K6	K7	M6	M7	N6	N7	P6	P7
.3937		0	10		+0	+.0006	+.0002	0	0	0	-.0002	-.0003	-.0004	-.0005	-.0006	-.0007	-.0008	-.0009	-.0010	-.0011
	.7087	-.0003		18	-.008	+.0013	+.0009	+.0011	+.0007	+.0004	+.0002	+.0004	+.0001	+.0002	-.0002	0	-.0004	-.0002	-.0006	-.0004
.7087		0	18		+0	+.0008	+.0003	0	0	0	-.0002	-.0004	-.0004	-.0006	-.0007	-.0008	-.0009	-.0011	-.0012	-.0014
	1.1811	-.0035		30	-.009	+.0016	+.0011	+.0013	+.0008	+.0005	+.0003	+.0005	+.0001	+.0002	-.0002	0	-.0004	-.0003	-.0007	-.0006
1.1811		0	30		+0	+.0010	+.0004	0	0	0	-.0002	-.0004	-.0005	-.0007	-.0008	-.0010	-.0011	-.0013	-.0015	-.0017
	1.9685	-.0045		50	-.011	+.0020	+.0013	+.0015	+.0010	+.0006	+.0004	+.0006	+.0001	+.0003	-.0002	0	-.0005	-.0003	-.0008	-.0007
1.9685		0	50		+0	+.0012	+.0004	0	0	0	-.0002	-.0005	-.0006	-.0008	-.0009	-.0012	-.0013	-.0015	-.0018	-.0020
	3.1496	-.0005		80	-.013	+.0024	+.0016	+.0018	+.0012	+.0007	+.0005	+.0007	+.0002	+.0004	-.0002	0	-.0006	-.0004	-.0010	-.0008
3.1496		0	80		+0	+.0014	+.0005	0	0	0	-.0002	-.0005	-.0007	-.0010	-.0011	-.0014	-.0015	-.0018	-.0020	-.0023
	4.7244	-.0006		120	-.015	+.0028	+.0019	+.0021	+.0014	+.0009	+.0006	+.0009	+.0002	+.0004	-.0002	0	-.0006	-.0004	-.0012	-.0009
4.7244		0	120		+0	+.0017	+.0006	0	0	0	-.0003	-.0006	-.0008	-.0011	-.0013	-.0016	-.0018	-.0020	-.0024	-.0027
	5.9055	-.0007		150	-.018	+.0033	+.0021	+.0025	+.0016	+.0010	+.0007	+.0010	+.0002	+.0005	-.0003	0	-.0008	-.0005	-.0014	-.0011
5.9055		0	150		+0	+.0017	+.0006	0	0	0	-.0003	-.0006	-.0008	-.0011	-.0013	-.0016	-.0018	-.0020	-.0024	-.0027
	7.0866	-.0010		180	-.025	+.0033	+.0021	+.0025	+.0016	+.0010	+.0007	+.0010	+.0002	+.0005	-.0003	0	-.0008	-.0005	-.0014	-.0011
7.0866		0	180		+0	+.0020	+.0006	0	0	0	-.0003	-.0006	-.0009	-.0013	-.0015	-.0018	-.0020	-.0024	-.0028	-.0031
	9.8425	-.0012		250	-.030	+.0038	+.0024	+.0028	+.0018	+.0011	+.0009	+.0012	+.0002	+.0005	-.0003	0	-.0009	-.0006	-.0016	-.0013
9.8425		0	250		+0	+.0022	+.0007	0	0	0	-.0003	-.0006	-.0011	-.0014	-.0016	-.0020	-.0022	-.0026	-.0031	-.0035
	12.4016	-.0014		315	-.035	+.0043	+.0027	+.0032	+.0020	+.0013	+.0010	+.0014	+.0002	+.0006	-.0004	0	-.0010	-.0006	-.0019	-.0014

Bearing Life and Load Ratings

How long a ball bearing will last under load depends on two groups of variables. First, there are the bearing's physical characteristics, which include how it is designed, the material from which it is made, and how it is manufactured. Secondly, there are the conditions under which it is applied, such as load, operating speed and temperature, the way it is mounted, and the way it is lubricated.

Even if a ball bearing is operated under ideal conditions — where it has been properly mounted, lubricated, protected from foreign particles, and not subjected to extreme temperature or speed — it will ultimately fail due to either material fatigue or wear. Fatigue failure results from the repeated stresses that are developed in the contact areas between the balls and raceways. Failure shows up as spalling of the load-carrying surfaces. Excessive wear occurs when operating conditions are other than ideal. These conditions are generally those which cause high friction and/or heat within the bearing.

PREDICTING BEARING LIFE

It is not possible to predict the exact fatigue life of an individual bearing. Instead, the designer of a system incorporating ball bearings must rely on the results of extensive research and testing done on the life of groups of identical bearings operated under identical conditions. Tests show that lifetimes of such operated bearings vary due to intricate differences between individual bearings. These lifetimes, however, follow definite statistical distributions. Load ratings, boundary dimensions, and tolerances for ball bearings and cylindrical roller bearings are computed from ABMA and ISO standards.

Such statistical distributions can be represented by equations which relate predicted bearing life to factors like the load it must bear, its operating speed, and the bearing's physical characteristics. It is up to the designer to then determine which bearing is best for a particular application by use of these equations.

L_{10}, *or rating life*, is the life most commonly used in load calculations. It is the life in units of either hours or millions of revolutions that 90% of a group of apparently identical ball bearings will complete or exceed. Another accepted form is L_{50}, or *median life*. It is the life which 50% of a group of bearings will complete or exceed. L_{50} is usually not more than five times L_{10}.

Another important definition is that of the *basic dynamic load rating* "C". For a radial ball bearing, the basic dynamic load rating is the constant radial load which a group of identical bearings with a stationary outer ring can theoretically endure for 500 hours at 33⅓ RPM (1,000,000 revolutions).

The relationship between bearing life and applied load can be expressed as:

Life in Revolutions:

$$L_{10} = \left(\frac{C}{P}\right)^3 \times 10^6$$

Life in Hours:

$$L_{10} = \left(\frac{C}{P}\right)^3 \frac{16667}{N}$$

Where:

- L_{10} = The rating life
- C = The basic dynamic capacity as shown in the catalog
- P = The equivalent radial load on the bearing in pounds
- N = Speed in RPM

Consult the factory for other life factors.

EQUIVALENT RADIAL LOAD

Bearings often must carry a combination of radial and thrust loads. The equations stated in the previous section are based solely on radially loaded bearings. Therefore, when radial and axial loads are present, an *equivalent radial load* (P) must be calculated. The equivalent radial load is the greater of:

$$P = XF_r + YF_a$$
$$P = F_r$$

Where:

- P = Equivalent radial load in pounds
- F_r = Applied radial load in pounds
- F_a = Applied axial load in pounds
- X = Radial load factor = 0.56
- Y = Axial load factor dependent on the magnitude of F_a/C_0
- C_0 = Catalog static load rating in pounds (definition to follow:

F_a/C_0	Y
0.014	2.30
0.028	1.99
0.056	1.71
0.084	1.55
0.11	1.45
0.17	1.31
0.28	1.15
0.42	1.04
0.56	1.00

C_0, the *static load rating,* is the non-rotating radial load which produces a maximum contact stress of 667,000 pounds per square inch at any point within the bearing.

When static load exceeds the catalog rating, a significant decrease in bearing smoothness and life can be expected when rotation is resumed.

As with dynamic load ratings, static loads are usually a combination of radial and thrust loads. Equivalent static load must therefore be calculated.

The static equivalent load for radial ball bearings is the greater of:

$P_0 = .6\ F_r + .5\ F_a$

$P_0 = F_r$

Where:

P_0 = Equivalent static radial load in pounds

F_r = Applied radial load in pounds

F_a = Applied axial load in pounds

EXAMPLES OF LIFE AND LOAD CALCULATIONS

Example 1:

Determine the L_{10} life hours of a 6203 ball bearing operating at 800 RPM with a radial load of 250 lbs.

The Basic Dynamic capacity from the catalog is C = 2153 lbs.

L_{10} = Unknown

C = 2153 lbs.

F_r = P = 250 lbs.

N = 800 RPM

$$L_{10} = \left(\frac{C}{P}\right)^3 \left(\frac{16667}{N}\right)$$

$$L_{10} = \left(\frac{2153}{250}\right)^3 \left(\frac{16667}{800}\right)$$

L_{10} = 13307 hours

Example 2:

Determine the minimum static and dynamic load ratings required to carry a 300 pound radial load, and 75 pound axial load for 3500 hours at 650 RPM.

C = Unknown	C_0 = Unknown
P = Unknown	P_0 = Unknown
Y = Unknown	X = .56
F_r = 300 lbs.	F_a = 75 lbs.
N = 650 RPM	L = 3500 hrs.

$P_0 = .6\ F_r + .5\ F_a = 217.5$ lbs.

or $P_0 = F_r = 300$ lbs.

Therefore P_0 = Co minimum = 300 lbs.

$F_a/C_0 = 75/300 = 0.25$

Then by interpolation Y = 1.19

Equivalent radial load

$P = XF_r + YF_a = .56\ (300) + 1.19\ (75) = 257.3$ lbs.

or $P = F_r = 300$ lbs. Therefore P = 300 lbs.

$$L_{10} = \left(\frac{C}{P}\right)^3 \left(\frac{16667}{N}\right)$$

or $$C = \left(\frac{L_{10}N}{16667}\right)^{1/3} P$$

or $$C = \left(\frac{(3500)(650)}{16667}\right)^{1/3} 300 = 1545 \text{ lbs.}$$

Answer: C_0 minimum = 300 lbs., C minimum = 1545 lbs.

Radial Internal Clearance Chart

Radial internal clearance is a measure of the radial looseness, or play between the inner and outer rings. Precision bearings are available in five classes of looseness. The amount of looseness necessary is dependent on many factors such as shaft alignment, shaft and housing fits, bearing speed, etc. As RPM, shaft misalignment, and press fits increase in magnitude, so should radial play.

RADIAL INTERNAL CLEARANCE, SINGLE ROW, RADIAL CONTACT, BALL BEARINGS

Tolerance Limits for Radial Internal Clearance of Single Row, Radial Contact Ball Bearings Under No Load

(Applicable to Bearings of ABEC-1, ABEC-5, ABEC-7 and ABEC-9 Tolerance Classes)

TOLERANCE LIMITS IN .0001 INCH

BASIC BORE DIAMETER		ACCEPTANCE LIMITS									
d – mm		C-2		STANDARD		C-3		C-4		C-5	
Over	Incl.	Low	High	Low	High	Low	High	Low	High	Low	High
2.5	6	0	3	1	5	3	9	—	—	—	—
6	10	0	3	1	5	3	9	6	11	8	15
10	18	0	3.5	1	7	4.5	10	7	13	10	18
18	24	0	4	2	8	5	11	8	14	11	19
24	30	0.5	4.5	2	8	5	11	9	16	12	21
30	40	0.5	4.5	2.5	8	6	13	11	18	16	25
40	50	0.5	4.5	2.5	9	7	14	12	20	18	29
50	65	0.5	6	3	11	9	17	15	24	22	35
65	80	0.5	6	4	12	10	20	18	28	26	41
80	100	0.5	7	4.5	14	12	23	21	33	30	47
100	120	1	8	6	16	14	26	24	38	35	55
120	140	1	9	7	19	16	32	28	45	41	63
140	160	1	9	7	21	18	36	32	51	47	71
160	180	1	10	8	24	21	40	36	58	53	79
180	200	1	12	10	28	25	46	42	64	59	91

For additional information concerning mounting procedures, lubrication, variable speeds and loads, safety or service factors, and other technical data necessary for proper bearing selection, contact our Engineering Department.