

## Engineering Information

### 1.0 Classification of NTN-BCA® Bearings

#### 1.1 Bearing Categories

Rolling element bearings are generally divided into two categories - ball and roller bearings. This catalog focuses specifically on NTN-BCA® ball bearings. For information on other NTN products including roller bearings, please consult your NTN sales representative.

#### 1.2 Rolling Bearing Construction

NTN-BCA® ball bearings generally consist of an inner ring, an outer ring, and rolling elements (balls). In addition, the majority of the bearings contain a retainer. The purpose of the retainer is to keep the rolling elements spaced apart and rotating freely. In some instances the retainer is intentionally omitted in order to maximize the load carrying capability of the bearing.

In addition to their basic components, these bearings can also be provided with a variety of supplementary components. Components such as grease, seals and housings can be included to tailor the bearings performance to the needs of the application.

#### 1.3 Classification

This catalog classifies the NTN-BCA® product line into 9 major classifications:

- Conrad Radial Ball Bearings
- Angular Contact Ball Bearings
- Mounted Bearings/Adapter Bearings
- Disc Bearings and Combined Ag Products
- Mast Guide/Chain Guide Bearings
- Swash Plate/Cradle Bearings
- Clutch Products
- Wheel Bearings
- Self Tensioning Idler Pulleys

These 9 major classifications can be broken down further and are shown in detail in the front of each section of the catalog.

#### 1.4 Characteristics of NTN-BCA® Ball Bearings

**1.4.1** NTN-BCA® ball bearings come in many shapes and sizes, each with its own distinctive features. When compared with sliding bearings, NTN-BCA® ball bearings have the following advantages:

- a. Lower coefficient of starting and running friction
- b. Dimensions are internationally standardized and interchangeable
- c. Are easily lubricated and consume little lubricant
- d. Generally one bearing can carry radial and axial loads
- e. When preloaded can offer increased system rigidity

#### 1.4.2 Ball Bearings versus Roller Bearings

Generally speaking, when comparing the same size ball and roller bearings, ball bearings exhibit lower frictional resistance and lower face runouts than their roller bearings counterparts. This makes ball bearings more suitable for use in applications where high precision, low torque and low vibration are required. On the other hand, roller bearings have a larger load carrying capacity which makes them more suitable for applications requiring heavy/shock loads and longer life.

#### 1.4.3 Radial and Thrust Bearings

Almost all rolling element bearings are capable of carrying radial and axial loads simultaneously. Generally, bearings with a contact angle of less than 45 degrees have a greater axial load capacity and are classified as thrust bearings. The remainder are classified as radial bearings.

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### 1.4.4 Standard versus Special Bearings

Bearings which are internationally standardized for shape and size are much more economical to use due to their worldwide availability. However, depending on the type of machine in which they are to be used and the expected application conditions, a non-standard or specially designed bearing may be more suitable. NTN-BCA® produces a number of specially designed bearings, most of which are represented in this catalog.

## 2.0 Bearing Selection

NTN-BCA® ball bearings come in a wide variety of shapes and sizes. The process of selecting the most appropriate bearing for the application can seem overwhelming. To facilitate the selection process and to be able to select the most suitable bearing for the job, it is necessary to analyze the application requirements completely. While there are no hard-and-fast rules in selecting a bearing, the following steps provide a general guideline in selecting the most appropriate bearing.

1. Thoroughly understand the function of the machine in which the bearing is to be used
2. Clearly define all performance criteria
3. Select bearing type
4. Select tolerance class based on performance requirements
5. Select bearing dimensions based on needed capacity
6. Select bearing arrangement, i.e., how many bearings
7. Select sealing and lubrication needs
8. Select desired mounting method

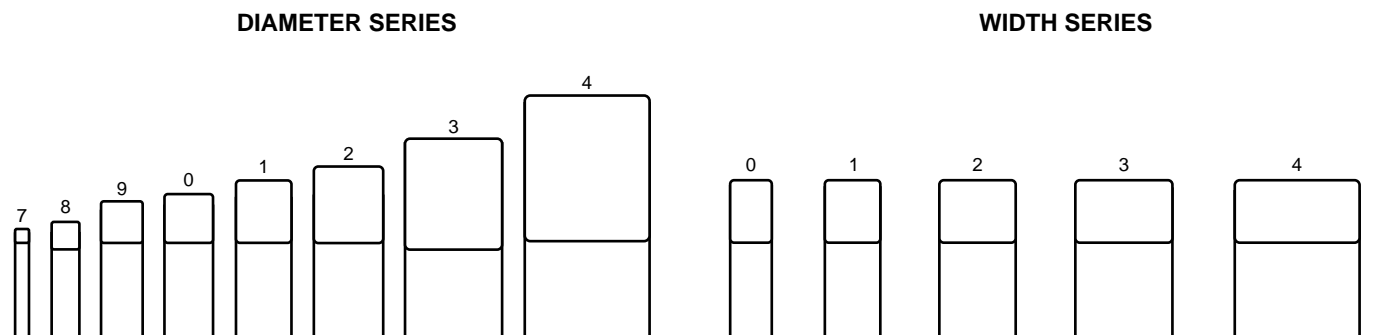
## 3.0 Boundary Dimension Standardization

To facilitate international interchangeability and economic bearing production, the boundary dimensions of rolling bearings have been standardized by the International Standards Organization (ISO) and the American Bearing Manufacturers Association (ABMA). The boundary dimensions that have been standardized include the bore diameter, the outside diameter, the width, and the external chamfer dimensions. As a general rule, bearing internal construction has not been standardized, leaving each manufacturer to optimize the internal space of the bearing.

For all types of standard bearings a combined series called the dimension series has been established. The dimension series is a combination of a diameter series and a width series. ISO 15 establishes eight major outside diameters for each standard bore diameter (diameter series) along with eight width designations for each bore and outside diameter series. Figure 3.1 shows the eight diameters and five width series for each bore diameter.

**Figure 3.1**

Graphical representation of the diameter and width series components of the dimensions series of the boundary plan for radial bearings.



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### 4.0 Bearing Tolerances

#### 4.1 Boundary dimensions

Bearing tolerances including dimensional and running accuracy are regulated by standards organizations such as ISO and ABMA. These standards prescribe dimensional tolerances and allowable error for boundary dimensions such as bore diameter, outside diameter, width and chamfer.

#### 4.2 Tolerance Classes

Tolerances and allowable error limitations are established for each tolerance grade or class in ANSI/ABMA Standard 20. ABMA establishes five distinct tolerance classes for radial ball bearings. In ascending order of precision, the tolerance classes are ABEC-1, ABEC-3, ABEC-5, ABEC-7, and ABEC-9. Most NTN-BCA® bearings are manufactured to ABEC-1 tolerances. Table 4.1 shows the ABEC-1 tolerances for radial ball bearing inner rings, while Table 4.2 shows the ABEC-1 tolerances for radial ball bearing outer rings.

**Table 4.1  
ABEC-1 Tolerances – Inner Ring**

(.0001")

Basic Bore Diameter				Single Plane Mean Bore Diameter Variation		Bore Diameter Variation In A Single Radial Plane			Mean Bore Diameter Variation	Ring Width Deviation		Ring Width Variation	Radial Runout Assembled Bearing Inner Ring	
Over	Incl	Over	Incl			100 Series Max.	200, 1200, 300, 1300, 400 Series Max.	Max.		High	Low			Max.
mm		inch								High	Low			
2.5	10	0.0984	0.3937	0	-3	3	2.5	2.5	0	-47	6	4		
10	18	0.3937	0.7087	0	-3	3	2.5	2.5	0	-47	8	4		
18	30	0.7087	1.1811	0	-4	4	3	3	0	-47	8	5		
30	50	1.1811	1.9685	0	-4.5	4.5	3.5	3.5	0	-47	8	6		
50	80	1.9685	3.1496	0	-6	7.5	4.5	4.5	0	-59	10	8		
80	120	3.1496	4.7244	0	-8	10	6	6	0	-79	10	10		
120	180	4.7244	7.0866	0	-10	12	7.5	7.5	0	-98	12	12		
180	250	7.0866	9.8425	0	-12	15	9	9	0	-118	12	16		

**Table 4.2  
ABEC-1 Tolerances - Outer Ring**

(.0001")

Basic Outer Diameter				Single Plane Mean Outer Diameter Variation		Outer Diameter Variation In A Single Radial Plane			Mean Outer Diameter Variation	Ring Width Deviation		Ring Width Variation	Radial Runout Assembled Bearing Inner Ring		
Over	Incl	Over	Incl			100 Series Max.	200, 1200, 300, 1300, 400 Series Max.	Sealed/ Shielded Bearings Max.		Max.	High			Low	Max.
mm		inch									High			Low	
18	30	0.7087	1.1811	0	-3.5	3.5	3	4.5	3	0	-47	8	6		
30	50	1.1811	1.9685	0	-4.5	4.5	3	6.5	3	0	-47	8	8		
50	80	1.9685	3.1496	0	-5	5	4	8	4	0	-59	10	10		
80	120	3.1496	4.7244	0	-6	7.5	4.5	10	4.5	0	-79	10	14		
120	150	4.7244	5.9055	0	-7	9	5.5	12	5.5	0	-98	12	16		
150	180	5.9055	7.0866	0	-10	12	7.5	15	7.5	0	-98	12	18		
180	250	7.0866	9.8425	0	-12	15	9	—	9	0	-118	12	20		
250	315	9.8425	12.4016	0	-14	17	10	—	10	0	-138	14	24		

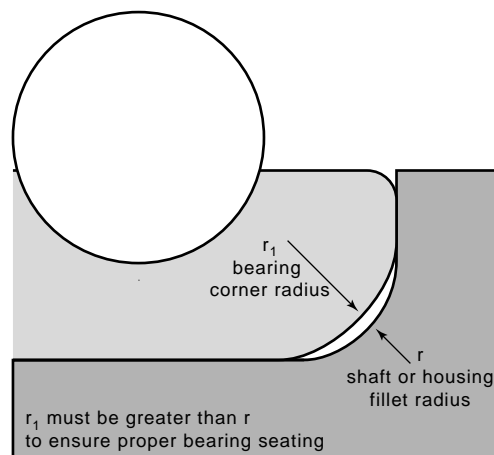
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### 4.3 Limits and Maximum Shaft & Housing Fillet Radii

#### 4.3.1 Corner Radius

For most BCA bearing products, a fillet radius “r” is shown in the bearing tables. This fillet radius represents the maximum shaft or housing radius that the bearing corner will clear. To ensure proper seating, it is imperative that the shaft and/or housing corner radius is no larger than the maximum fillet radius shown in the bearing tables.

Figure 4.1



## 5.0 Basic Load Rating and Life

### 5.1 Bearing Life

Over time, even under normal operating conditions, bearings will eventually fail due to material fatigue from repeated compressive stresses generated by the application of load. The effective life of a bearing is typically defined in terms of the total number of revolutions sustained before the onset of fatigue failure of the raceways or the rolling elements.

In addition to flaking, there are many other application related reasons for bearing failure. Common non-fatigue related failure modes include seizure, fracture, retainer failure and poor lubrication. Many of these failure modes are caused by improper installation, improper lubrication selection, faulty sealing, inaccurate bearing selection or other uncontrollable environmental conditions. For these reasons bearing fatigue life calculations are used primarily as a guideline for predicting life and as a means for comparing one bearing design to another.

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### 5.2 Basic Dynamic Load Rating

The basic dynamic load rating represents the constant load that could be applied to the bearing for one million revolutions (the basic rating life). The basic dynamic load ratings shown in the bearing tables of this catalog are for bearings constructed of NTN-BCA<sup>®</sup> standard materials using standard manufacturing techniques. Please consult NTN Engineering for load ratings and life adjustment factors for bearings constructed of special materials or using special manufacturing techniques.

### 5.3 Basic Rated Life

A group of identical bearings subjected to identical loads and operating conditions will exhibit varying lives. The difference is attributed to the difference in fatigue of the material itself. The difference is considered statistically when calculating bearing life defined as follows:

The basic rated life is based on a statistical model which is expressed as the total number of revolutions 90% of the bearings in an identical group exposed to identical operating conditions will attain or surpass before material fatigue (flaking) occurs. For bearings operating at fixed constant speeds, the basic rated life (90% reliability) is expressed as the total number of hours of operation.

### 5.4 Basic Life Equations

The relationship between the basic rated life in revolutions, the dynamic load rating and the bearing load is given in equation 5.1.

$$\text{Equation 5.1} \quad L_{10} = \left( \frac{C}{P} \right)^p$$

Where:  $L_{10}$ : Basic rated life ( $10^6$  revolutions)  
 C: Basic dynamic load rating (lbs.)  
 P: Dynamic equivalent load (lbs.)  
 p: Exponent – 3 for ball bearings

The basic rated life can also be expressed in hours as shown in equation 5.2.

$$\text{Equation 5.2} \quad L_{10h} = \frac{10^6}{60n} \left( \frac{C}{P} \right)^p$$

Where:  $L_{10h}$ : Basic rated life (hours)  
 C: Basic dynamic load rating (lbs.)  
 P: Dynamic equivalent load (lbs.)  
 p: Exponent – 3 for ball bearings  
 n: Speed (rpm)

When several bearings are used in the same machine, the probability of failure must be considered for all bearings as a whole. The system bearing life is a way of predicting bearing life before even one of the bearings fails due to rolling contact fatigue. Equation 5.3 represents the system bearing life.

$$\text{Equation 5.3} \quad L_{sys} = \frac{1}{\left( \frac{1}{L_1^e} + \frac{1}{L_2^e} + \dots + \frac{1}{L_n^e} \right)^{1/e}}$$

Where:  $L_{sys}$ : System life (hours)  
 $L_n$ : Life of individual bearings (hours)  
 e: 10/9 for ball bearings

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Bearings are often subjected to a duty cycle, i.e., loading conditions that vary at regular intervals. By knowing the life at each individual condition and the percentage of time at each of those conditions, the duty cycle life can be expressed as shown in equation 5.4.

$$\text{Equation 5.4 } L_m = \left( \sum \phi_j / L_j \right)^{-1}$$

Where:  $L_m$ : Duty cycle life  
 $\phi_j$ : % time at individual condition  
 $L_j$ : Life at individual condition

### 5.5 Life Adjustment Factors

The standard method for predicting life is to calculate a 90% reliable life as shown in section 5.3. However, it is sometimes desirable to adjust that calculated life to account for higher reliabilities, special materials, heat treatments, manufacturing processes, lubricants and operating conditions.

All of these factors can be considered when calculating bearing life according to equation 5.5.

$$\text{Equation 5.5 } L_{adj} = a_1 a_2 a_3 \left( \frac{C}{P} \right)^p$$

Where:  $L_{adj}$ : Adjusted life in millions of revolutions  
 $a_1$ : Reliability adjustment factor  
 $a_2$ : Material adjustment factor  
 $a_3$ : Operating conditions adjustment factor  
 $p$ : Exponent – 3 for ball bearings

#### 5.5.1 Life adjustment factor for reliability, $a_1$

The adjustment factors for reliabilities greater than 90% are shown in Table 5.1

**Table 5.1 Life Adjustment Factor For Reliability –  $a_1$**

Reliability %	$L_n$	Life Adjustment Factor – $a_1$
90	$L_{10}$	1.00
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

#### 5.5.2 Life adjustment factor for special materials/processes, $a_2$

The basic dynamic load ratings shown in this catalog reflect standard materials and processing techniques employed by NTN-BCA®. Therefore, as long as the operating temperature is 250 °F or lower, the standard life adjustment factor for NTN-BCA® ABEC-1 ball bearings is 1.0. Please consult your NTN sales representative for special materials and/or heat treatments and their corresponding  $a_2$  factors.

#### 5.5.3 Life adjustment for operating conditions, $a_3$

Operating conditions which may impact the service life of a bearing and which are included in this category are:

1. Lubrication at operating speed and temperature
2. Conditions causing changes in material properties (ex. Excess heat)
3. Foreign particle contamination
4. Mounting conditions

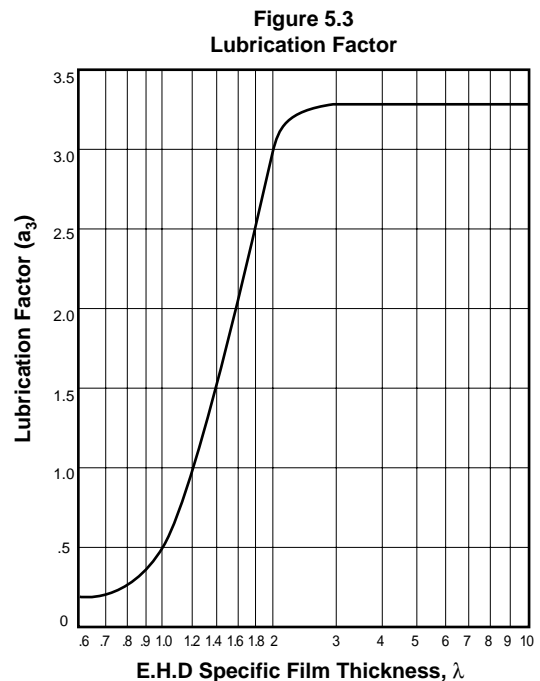
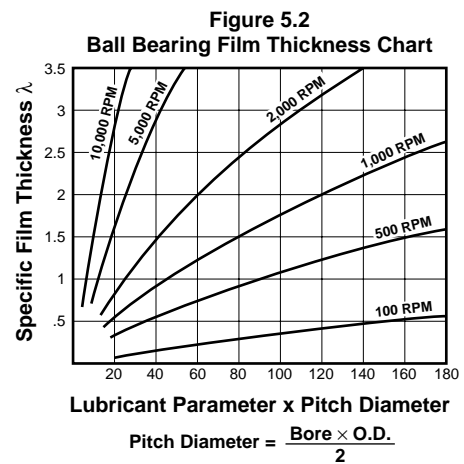
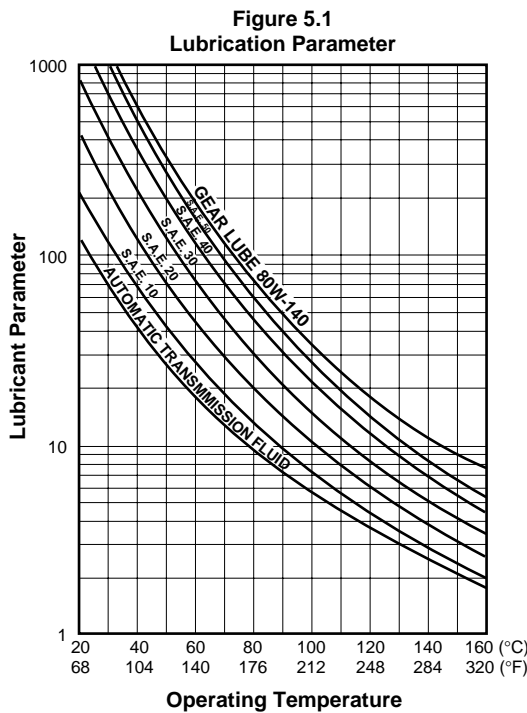
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### 5.5.3.1 Lubrication adjustment factor

The lubricant selected for the application, the operating temperature and the bearing speed all combine to affect bearing life. When any of these parameters deviates significantly from standard conditions, the life of the bearing may need to be adjusted. In general, higher viscosity lubricants, higher operating speeds and lower operating temperatures yield an adjustment factor greater than 1.0. On the contrary, lower viscosity lubricants, lower speeds or higher temperatures may reduce life, prompting the need to use an operating conditions life adjustment factor less than 1 ( $a_3 < 1.0$ ).

When considering the need to adjust life due to lubricant, it does not matter if grease or oil is used. If grease is used, simply use the grease's base oil to establish the lubrication factor. When using multi-grade lubricants, the lower grade viscosity oil is used to establish the lubrication factor. Figures 5.1 to 5.3 are used to establish the lubrication factor.

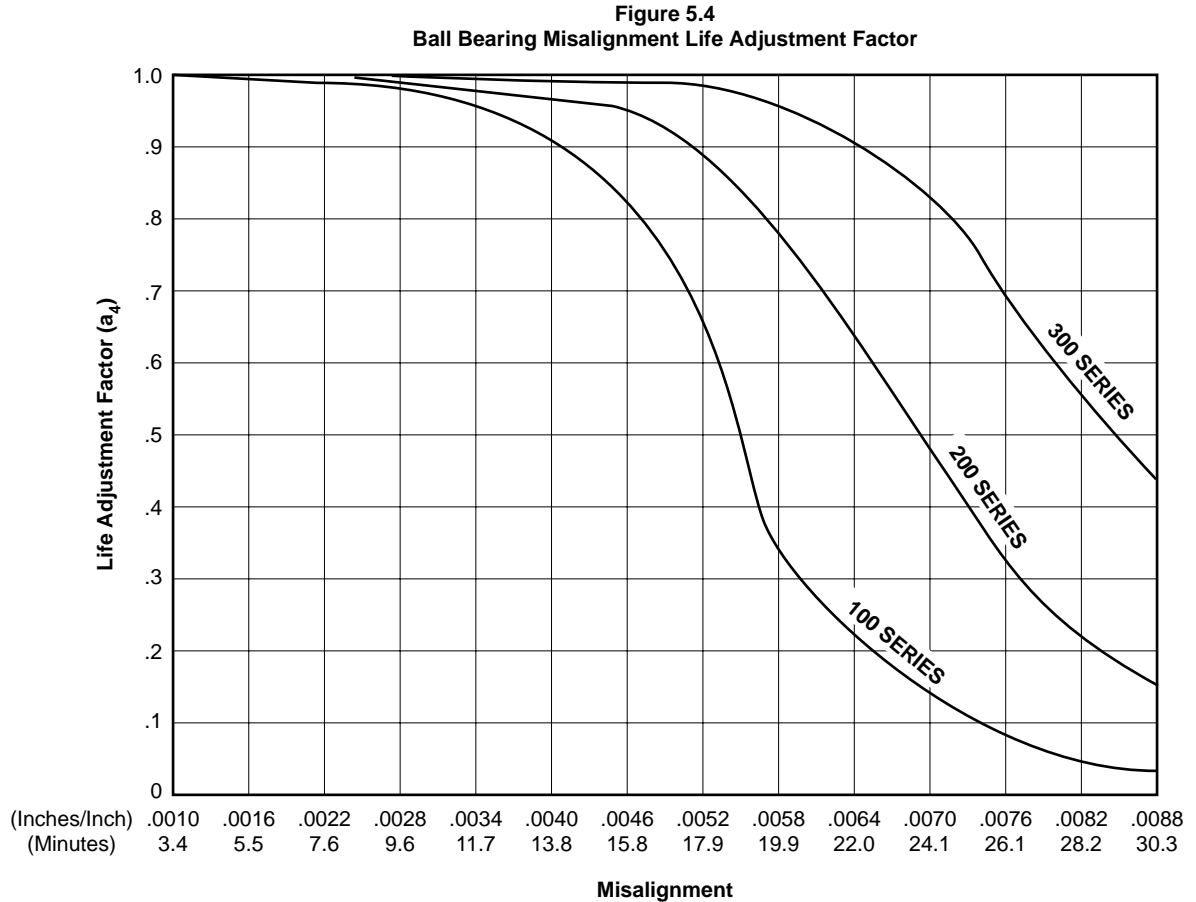
1. Determine the lubrication parameter from Figure 5.1
2. Multiply the lubrication parameter by pitch diameter and use Figure 5.2 to determine specific film thickness.
3. Use the specific film thickness determined in Figure 5.2 in Figure 5.3 to determine the lubrication adjustment factor.



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### 5.5.3.2 Adjustment factor for mounting irregularities (misalignment)

Due to the limitations of machining shafts, housings and other mating components, an ideal mounted bearing condition may not be achievable. In most applications, a certain amount of misalignment will be present. A small amount of misalignment is allowed for when bearing load ratings are determined. However, a reduction of calculated  $L_{10}$  life should be considered when misalignment exceeds the maximum base value of four (4) minutes. Figure 5.4 is used to establish the adjustment factor for misalignment.



### 5.6 Basic Static Load Rating

When stationary rolling element bearings are subjected to static loads, small localized deformations occur between the rolling element and the adjacent raceway surface. As long as the loads do not exceed the static capacity of the bearing, the deformations will be elastic in nature, i.e., the material will spring back once the load is removed. The amount of deformity increases with increasing loads, and if the load exceeds the static capacity of the bearing, the material will permanently deform. It has been found through experience that a permanent deformity of 0.0001 times the rolling element diameter can be tolerated without interrupting the smooth operation of the bearing.

The basic static load rating refers to the fixed static load limit at which a specified amount of permanent deformation occurs. For ball bearings, the stress associated with the limiting permanent deformation is 4200 MPa.

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### 5.7 Limiting Static Load

The limiting static load depends on the requirements of the application such as rolling friction and smooth operation. The limiting static load may be greater than or less than the static load rating.

Equation 5.6 can be used to determine the static safety factor for a given applied static load. In addition, Table 5.2 shows minimum static safety factors.

**Equation 5.6** 
$$S_o = \frac{C_o}{P_{o \max}}$$

**Table 5.2 Minimum safety factor values  $S_o$**

Operating Conditions	Ball Bearings	Note 1. When vibration and/or shock loads are present, a load factor based on the shock load needs to be included in the $P_{o \max}$ value
High rotational accuracy demand	2	
Normal accuracy rotating demand (Universal Application)	1	
Slight rotational accuracy deterioration permitted (Low speed, Heavy loading, etc.)	0.5	

## 6.0 Equivalent Loads

### 6.1 Dynamic equivalent loads

NTN-BCA® ball bearings are often subjected to radial and axial loads simultaneously. The dynamic equivalent load represents the hypothetical load acting at the center of the bearing which gives the bearing the same life as if only a radial or axial load was applied. For radial bearings, this hypothetical load is expressed as a pure radial load and is referred to as the dynamic equivalent radial load ( $P_r$ ). The dynamic equivalent radial load is expressed by equation 5.7

**Equation 5.7** 
$$P_r = XF_r + YF_a$$

Where:  $P_r$ : Dynamic equivalent radial load (lbs.)  
 $F_r$ : Actual radial load (lbs.)  
 $F_a$ : Actual axial load (lbs.)  
 X: Radial load factor  
 Y: Axial load factor

$\frac{F_a}{C_{or}}$	$e$	$\frac{F_a}{F_r} \leq e$		$\frac{F_a}{F_r} > e$	
		X	Y	X	Y
0.010	0.18				2.46
0.020	0.20				2.14
0.040	0.24				1.83
0.070	0.27				1.61
0.10	0.29	1	0	0.56	1.48
0.15	0.32				1.35
0.20	0.35				1.25
0.30	0.38				1.13
0.40	0.41				1.05
0.50	0.44				1.00

static  $P_{or} = 0.6F_r + 0.5F_a$   
 When  $P_{or} < F_r$  use  $P_{or} < F_r$

### 6.2 Static Equivalent Load

The static equivalent load is the hypothetical pure static radial load that would cause the same permanent deformation in the raceways as a combination of radial and static loads. For radial bearings the static equivalent radial load can be expressed as shown in equation 5.8 or 5.9 whichever provides the larger result.

**Equation 5.8** 
$$P_{or} = X_o F_r + Y_o F_a$$

**Equation 5.9** 
$$P_{or} = F_r$$

Where:  $P_{or}$ : Static equivalent radial load  
 $X_o$ : Static radial load factor  
 $Y_o$ : Static axial load factor  
 $F_r$ : Actual radial load  
 $F_a$ : Actual axial load

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### 7.0 Mounting And Fitting Practice Shaft And Housing Mounting Data

#### 7.1 Shaft And Housing Fits

The tables on the following pages contain the recommended bearing seat diameters for shafts and housings for all standard NTN-BCA® ball bearings listed in this catalog and are based on the standards of the American Bearing Manufacturers Association. The tables also include the maximum and minimum bearing bores and outside diameters along with resulting fits.

In order to obtain maximum ball bearing service life, it is imperative that proper shaft and housing fits be selected and used. When excessively tight fits are used, preloading of the bearings can occur. This results in fatigue failure of the balls and/or raceways. Preloading can also cause a breakdown of the lubricant film which results in overheating and subsequent failure. When excessively loose fits are employed, slippage of the rings may occur relative to the mating surface. This movement results in vibration, overheating and damage to the bearing mounting.

As a general rule it is necessary to press fit the rotating ring of a bearing against its respective mounting member. The stationary ring is then mounted with a line to line or close push fit against its respective mounting. The amount of press and the amount of looseness depend on the loading and conditions of the application, such as shaft and housing material and environmental conditions. In most applications the shaft is rotating and the housing is stationary. Therefore, the bearing inner ring must be press fitted to the shaft to prevent creeping and subsequent shaft damage. The outer ring should be a push fit into the housing. The push fit allows for axial movement of the unclamped outer ring due to thermal expansion of the shaft or housing and prevents undue thrust loading. The push fit also facilitates ease of installation.

In applications where the housing rotates and the shaft is stationary (such as idler pulleys) the bearing should be mounted with the outer ring press fitted into the housing bore and the inner ring a close push fit on the shaft.

In applications where both the shaft and the housing are rotating, it may be necessary to press fit both the inner and outer rings against their respective mountings. Aluminum or light alloy housings normally require a slightly tighter fit than shown in the tables. For specific recommendations on special applications consult your NTN sales representative or Application Engineer.

Tables 7.1 through 7.4 on the following pages provide recommended shaft and housing seat diameters for rotating and stationary components. In addition, bearing bore and outside diameter tolerances and mean resulting fits are shown.

#### 7.2 Shaft and Housing Finish

The shaft and housing dimensions specified in the tables are within very close limits. In order to achieve these dimensions, it will almost always be necessary to use a grinding operation to obtain the necessary finish and precision, especially on shafts. The shaft should also be perfectly round and free from taper. Housing bores should have a finish of 125 micro inches maximum for normal applications. The housing bore should also be perfectly round and free of taper. In addition, the housing shoulders should be square with the bore to prevent outer ring misalignment.

#### 7.3 Specification of Internal Clearance

When a bearing ring is press fitted over the mounting seat, the interference results in a reduction of the bearing internal clearance. NTN-BCA® ball bearings are assembled with internal clearance which will yield the correct operating internal clearance when the recommended shaft and housing diameters are used. When heavy press fits are employed, it may be necessary to use a bearing with internal clearance greater than standard. The correct internal clearance may be obtained by specification when ordering.

#### 7.4 Shaft and Housing Shoulder Diameters

When bearings are mounted onto shafts and into housings, it is necessary to provide adequate backing. Tables 7.5 and 7.6 provide the minimum and maximum shaft and housing shoulder diameters.

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**Table 7.1 Shaft Fits  
ABEC 1 Tolerances  
Single Row Radial 100-200-300-1200-1300 Series  
Single Row Angular Contact 7100-7200-7300 Series  
Double Row 5200-5300 Series**

The shaft fits shown below are to be used for normal operating conditions. In certain applications modifications to these dimensions may be necessary. The dimensions shown are for solid steel shafting, hardened and ground. For abnormal operating conditions (soft shafts, heavy shock loads or vibration) correct fits can be obtained by consulting the NTN Applications Engineering Department.

Bearing Number	Bearing Bore Diameter		Shaft Revolving			Shaft Stationary		
	Max.	Min.	Shaft Diameter Max.	Shaft Diameter Min.	Resultant Fit (.0001")	Shaft Diameter Max.	Shaft Diameter Min.	Resultant Fit (.0001")
All Series	Inch							
0	.3937	.3934	.3939	.3936	5 Tight to 1 Loose	.3935	.3931	6 Loose to 1 Tight
1	.4724	.4721	.4728	.4725	7 Tight to 1 Tight	.4721	.4717	7 Loose to 0 Tight
2	.5906	.5903	.5910	.5907				
3	.6693	.6690	.6697	.6694				
4	.7874	.7870	.7879	.7875	9 Tight to 1 Tight	.7871	.7866	8 Loose to 1 Tight
5	.9843	.9839	.9848	.9844				
6	1.1811	1.1807	1.1816	1.1812				
7	1.3780	1.3755	1.3785	1.3781	10 Tight to 1 Tight	1.3776	1.3770	10 Loose to 1 Tight
8	1.5748	1.5743	1.5753	1.5749				
9	1.7717	1.7712	1.7722	1.7718				
10	1.9685	1.9680	1.9690	1.9686				
11	2.16584	2.1648	2.1660	2.1665	12 Tight to 1 Tight	2.1650	2.1643	11 Loose to 2 Tight
12	2.3622	2.3616	2.3628	2.3623				
13	2.5591	2.5585	2.5597	2.5592				
14	2.7559	2.7553	2.7565	2.7560				
15	2.9528	2.9522	2.9534	2.9529				
16	3.1496	3.1490	3.1502	3.1497				
17	3.3465	3.3457	3.3472	3.3466	15 Tight to 1 Tight	3.3460	3.3451	14 Loose to 3 Tight
18	3.5433	3.5425	3.5440	3.5434				
19	3.7402	3.7394	3.7409	3.7403				
20	3.9370	3.9362	3.9377	3.9371				
21	4.1339	4.1331	4.1346	4.1340				
22	4.3307	4.3299	4.3314	4.3308				
23	4.5276	4.5268	4.5283	4.5277				
24	4.7244	4.7236	4.7251	4.7245				

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**Table 7.2 Housing Fits**  
**ABEC 1 Tolerances**  
**Single Row Radial 100-200-300-1200-1300 Series**  
**Single Row Angular Contact 7100-7200-7300 Series**  
**Double Row 5200-5300 Series**

The housing fits shown below are to be used for normal operating conditions. They are based on **Cast Iron or Steel Housings**. Closer tolerances in general, are required for soft metal housings, especially when rotating, and those housings which experience heavy or vibratory loads. Housings, should have a smooth finish such as produced by reaming or grinding.

100 7100	Series 200 1200 5200	300 1300 5300 7300	Bearing Outer Diameter		Housing Stationary			Housing Rotating		
			Max.	Min.	Housing Diameter		Resultant Fit (.0001")	Housing Diameter		Resultant Fit (.0001")
					Max.	Min.		Max.	Min.	
Basic Bore Number			Inch							
0	—	—	1.0236	1.0232	1.0241	1.0236	9 Loose to 0 Loose	1.0231	1.0226	10 Tight to 1 Tight
1	—	—	1.1024	1.1020	1.1029	1.1024		1.1019	1.1014	
—	0	—	1.1811	1.1807	1.1816	1.1811		1.1806	1.1801	
2	1	—	1.2598	1.2593	1.2604	1.2598	11 Loose to 0 Loose	1.2593	1.2587	11 Tight to 0 Tight
3	2	0	1.3780	1.3775	1.3786	1.3780		1.3775	1.3769	
—	—	1	1.4567	1.4562	1.4573	1.4567		1.4562	1.4556	
—	3	—	1.5748	1.5743	1.5754	1.5748		1.5743	1.5737	
4	—	2	1.6535	1.6530	1.6541	1.6535		1.6530	1.6524	
5	4	3	1.8504	1.8499	1.8510	1.8504	1.8499	1.8493		
—	5	4	2.0472	2.0467	2.0479	2.0472	12 Loose to 0 Loose	2.0466	2.0459	13 Tight to 1 Tight
6	—	—	2.1654	2.1649	2.1661	2.1654		2.1648	2.1641	
7	6	5	2.4409	2.4404	2.4416	2.4409		2.4403	2.4396	
8	—	—	2.6772	2.6767	2.6779	2.6772		2.6766	2.6759	
—	7	6	2.8346	2.8341	2.8353	2.8346		2.8340	2.8333	
9	—	—	2.9528	2.9523	2.9535	2.9528		2.9522	2.9515	
10	8	7	3.1496	3.1491	3.1503	3.1496	3.1490	3.1483		
—	9	—	3.3465	3.3459	3.3474	3.3465	15 Loose to 0 Loose	3.3458	3.3449	16 Tight to 1 Tight
11	10	8	3.5433	3.5427	3.5442	3.5433		3.5426	3.5417	
12	—	—	3.7402	3.7396	3.7411	3.7402		3.7395	3.7386	
13	11	9	3.9370	3.9364	3.9379	3.9370		3.9363	3.9354	
14	12	10	4.3307	4.3301	4.3316	4.3307		4.3300	4.3291	
15	—	—	4.5276	4.5270	4.5285	4.5276		4.5269	4.5260	
—	13	11	4.7244	4.7238	4.7253	4.7244		4.7237	4.7228	
16	14	—	4.9213	4.9205	4.9223	4.9213	18 Loose to 0 Loose	4.9204	4.9194	19 Tight to 1 Tight
17	15	12	5.1181	5.1173	5.1191	5.1181		5.1172	5.1162	
18	16	13	5.5118	5.5110	5.5128	5.5118		5.5109	5.5099	
19	—	—	5.7087	5.7079	5.7097	5.7087		5.7078	5.7068	
20	17	14	5.9055	5.9047	5.9065	5.9055		5.9046	5.9036	
21	18	15	6.2992	6.2982	6.3002	6.2992	20 Loose to 0 Loose	6.2983	6.2973	19 Tight to 1 Loose
22	19	16	6.6929	6.6919	6.6939	6.6929		6.6920	6.6910	
24	20	17	7.0866	7.0856	7.0876	7.0866		7.0857	7.0875	
—	21	18	7.4803	7.4791	7.4815	7.4803	24 Loose to 0 Loose	7.4793	7.4781	22 Tight to 2 Loose
—	22	19	7.8740	7.8728	7.8752	7.8740		7.8730	7.8718	
—	24	20	8.4646	8.4634	8.4658	8.4646		8.4636	8.4624	
—	—	21	8.8583	8.8571	8.8595	8.8583		8.8573	8.8561	
—	—	22	9.4488	9.4476	9.4500	9.4488		9.4478	9.4466	

## Engineering Information

**Table 7.3 Shaft Fits  
ABEC 1 Tolerances  
XLS Series Bearings**

Bearing Number	Bearing Bore Diameter		Shaft Rotating			Shaft Stationary		
	Max.	Min.	Shaft Diameter		Mean Fit (.0001")	Shaft Diameter		Mean Fit (.0001")
			Max.	Min.		Max.	Min.	
	Inch							
XLS-1- $\frac{1}{8}$	1.1250	1.1245	1.1255	1.1251	5.5 Tight	1.1246	1.1240	4.5 Loose
XLS-1- $\frac{1}{4}$	1.2500	1.2495	1.2505	1.2501	5.5 Tight	1.2496	1.2490	4.5 Loose
XLS-1- $\frac{3}{4}$	1.7500	1.7495	1.7505	1.7501	5.5 Tight	1.7496	1.7490	4.5 Loose
XLS-1- $\frac{7}{8}$	1.8750	1.8745	1.8755	1.8751	5.5 Tight	1.8746	1.8740	4.5 Loose
XLS-2- $\frac{1}{4}$	2.2500	2.2494	2.2506	2.2501	6.5 Tight	2.2496	2.2489	4.5 Loose
XLS-2- $\frac{3}{8}$	2.3750	2.3744	2.3756	2.3751	6.5 Tight	2.3746	3.3739	4.5 Loose
XLS-2- $\frac{1}{2}$	2.5000	2.4994	2.5006	2.5001	6.5 Tight	2.4996	2.4989	4.5 Loose
XLS-2- $\frac{5}{8}$	2.6250	2.6244	2.6256	2.6251	6.5 Tight	2.6246	2.6239	4.5 Loose
XLS-2- $\frac{3}{4}$	2.7500	2.7494	2.7506	2.7501	6.5 Tight	2.7496	2.7489	4.5 Loose
XLS-2- $\frac{7}{8}$ ❶	2.8788	2.8782	2.8794	2.8789	6.5 Tight	2.8784	2.8777	4.5 Loose
XLS-3	3.0000	2.9994	3.0006	3.0001	6.5 Tight	2.9996	2.9989	4.5 Loose
XLS-3- $\frac{1}{4}$	3.2500	3.2492	3.2507	3.2501	8.0 Tight	3.2495	3.2487	5.0 Loose
XLS-3- $\frac{3}{8}$	3.3750	3.3742	3.3757	3.3751	8.0 Tight	3.3745	3.3737	5.0 Loose
XLS-3- $\frac{1}{2}$	3.5000	3.4992	3.5007	3.5001	8.0 Tight	3.4995	3.4987	5.0 Loose
XLS-3- $\frac{3}{4}$	3.7500	3.7492	3.7507	3.7501	8.0 Tight	3.7495	3.7487	5.0 Loose
XLS-4	4.0000	3.9992	4.0007	4.0001	8.0 Tight	3.9995	3.9987	5.0 Loose
XLS-4- $\frac{1}{8}$	4.1250	4.1242	4.1257	4.1251	8.0 Tight	4.1245	4.1237	5.0 Loose
XLS-4- $\frac{1}{4}$	4.2500	4.2492	4.2507	4.2501	8.0 Tight	4.2495	4.2487	5.0 Loose
XLS-4- $\frac{1}{2}$	4.5000	4.4992	4.5007	4.5001	8.0 Tight	4.4995	4.4987	5.0 Loose
XLS-4- $\frac{3}{4}$	4.7500	4.7490	4.7508	4.7501	9.5 Tight	4.7494	4.7485	5.5 Loose
XLS-5	5.0000	4.9990	5.0008	5.0001	9.5 Tight	4.9994	4.9985	5.5 Loose
XLS-5- $\frac{1}{8}$	5.1181	5.1171	5.1189	5.1182	9.5 Tight	5.1175	5.1166	5.5 Loose
XLS-5- $\frac{1}{2}$	5.5000	5.4990	5.5008	5.5001	9.5 Tight	5.4994	5.4985	5.5 Loose
XLS-6- $\frac{1}{4}$	6.2500	6.2490	6.2508	6.2501	9.5 Tight	6.2494	6.2485	5.5 Loose
XLS-6- $\frac{3}{4}$ ❶	6.7880	6.7860	6.7888	6.7881	14.5 Tight	6.7874	6.7865	5.5 Loose
XLS-7	7.0000	6.9990	7.0008	7.0001	9.5 Tight	6.9994	6.9985	5.5 Loose
XLS-8- $\frac{3}{4}$ ❶	8.8090	8.8050	8.8099	8.8092	25.5 Tight	8.8084	8.8073	8.5 Loose

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## Engineering Information

**Table 7.4 Housing Fits  
ABEC 1 Tolerances  
XLS Series Bearings**

Bearing Number	Bearing Outer Diameter		Housing Stationary			Housing Rotating		
	Max.	Min.	Housing Bore		Mean Fit (.0001")	Housing Bore		Mean Fit (.0001")
			Max.	Min.		Max.	Min.	
	Inch							
XLS-1- $\frac{1}{8}$	2.1250	2.1245	2.1250	2.1257	6.0 Loose	2.1241	2.1248	3.0 Tight
XLS-1- $\frac{1}{4}$	2.2500	2.2495	2.2500	2.2507	6.0 Loose	2.2491	2.2498	3.0 Tight
XLS-1- $\frac{3}{4}$	3.0000	2.9995	3.0000	3.0007	6.0 Loose	2.9991	2.9998	3.0 Tight
XLS-1- $\frac{7}{8}$	3.1875	3.1896	3.1875	3.1884	7.5 Loose	3.1864	3.1873	3.5 Tight
XLS-2- $\frac{1}{4}$	3.5625	3.5619	3.5625	2.5634	7.5 Loose	3.5614	3.5623	3.5 Tight
XLS-2- $\frac{3}{8}$	3.7500	3.7494	3.7500	3.7509	7.5 Loose	3.7489	3.7498	3.5 Tight
XLS-2- $\frac{1}{2}$	3.8750	3.8742	3.8750	3.8756	7.5 Loose	3.8739	3.8746	3.5 Tight
XLS-2- $\frac{5}{8}$	4.1250	4.1244	4.1250	4.1259	7.5 Loose	4.1239	4.1248	3.5 Tight
XLS-2- $\frac{3}{4}$	4.1250	4.1244	4.1250	4.1259	7.5 Loose	4.1239	4.1248	3.5 Tight
XLS-2- $\frac{7}{8}$ ❶	4.1875	4.1869	4.1875	4.1884	7.5 Loose	4.1864	4.1873	3.5 Tight
XLS-3	4.4993	4.4987	4.4993	4.5002	7.5 Loose	4.4982	4.4991	3.5 Tight
XLS-3- $\frac{1}{4}$	4.7500	4.7492	4.7500	4.7510	9.0 Loose	4.7487	4.7497	4.0 Tight
XLS-3- $\frac{3}{8}$	5.0000	4.9992	5.0000	5.0010	9.0 Loose	4.9987	4.9997	4.0 Tight
XLS-3- $\frac{1}{2}$	5.0000	4.9992	5.0000	5.0010	9.0 Loose	4.9987	4.9997	4.0 Tight
XLS-3- $\frac{3}{4}$	5.2500	5.2492	5.2500	5.2510	9.0 Loose	5.2487	5.2497	4.0 Tight
XLS-4	5.6250	5.6242	5.6250	5.6260	9.0 Loose	5.6237	5.6247	4.0 Tight
XLS-4- $\frac{1}{8}$	6.0000	5.9990	6.0000	6.0010	10.0 Loose	5.9987	5.9997	3.0 Tight
XLS-4- $\frac{1}{4}$	6.0000	5.9990	6.0000	6.0010	10.0 Loose	5.9987	5.9997	3.0 Tight
XLS-4- $\frac{1}{2}$	6.2490	6.2480	6.2490	6.2500	10.0 Loose	6.2477	6.2487	3.0 Tight
XLS-4- $\frac{3}{4}$	6.5000	6.4990	6.5000	6.5010	10.0 Loose	6.4987	6.4997	3.0 Tight
XLS-5	7.0000	6.9990	7.0000	7.0010	10.0 Loose	6.9987	6.9997	3.0 Tight
XLS-5- $\frac{1}{8}$	7.0866	7.0856	7.0866	7.0876	10.0 Loose	7.0853	7.0863	3.0 Tight
XLS-5- $\frac{1}{2}$	7.5000	7.4988	7.5000	7.5011	11.5 Loose	7.4985	7.4997	3.0 Tight
XLS-6- $\frac{1}{4}$	8.4990	8.4978	8.4990	8.5001	11.5 Loose	8.4975	8.4987	3.0 Tight
XLS-6- $\frac{3}{4}$ ❶	9.0000	8.9988	9.0000	9.0011	11.5 Loose	8.9985	8.9997	3.0 Tight
XLS-7	9.5000	9.4988	9.5000	9.5011	11.5 Loose	9.4985	9.4997	3.0 Tight
XLS-8- $\frac{3}{4}$ ❶	11.7500	11.7480	11.7500	11.7513	16.5 Loose	11.7484	11.7496	3.0 Tight

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## Engineering Information

**Table 7.5 Shaft and Housing Shoulder Diameters**  
**Single Row Radial 100-200-300-1200-1300 Series**  
**Single Row Angular Contact 7200-7300 Series**  
**Double Row 5200-5300 Series**

The **Minimum Shaft Shoulder Diameters and Maximum Housing Shoulder Diameters** shown below and on the following page conform to ABMA Standards. These tables are recommended for the majority of applications. However, under certain design limitations, modifications of these diameters may be required. Consult your NTN Application Engineering Department for specific recommendations.

Bearing Bore Number	Extra Light Series 100		Light Series 200-1200-5200-7200		Medium Series 300-1300-5300-7300	
	Minimum Shaft Shoulder Diameter S	Maximum Housing Shoulder Diameter H	Minimum Shaft Shoulder Diameter S	Maximum Housing Shoulder Diameter H	Minimum Shaft Shoulder Diameter S	Maximum Housing Shoulder Diameter H
	Inches					
0	.47	.95	.50	.98	.50	1.18
1	.55	1.02	.58	1.06	.63	1.22
2	.67	1.18	.69	1.18	.75	1.42
3	.75	1.30	.77	1.34	.83	1.61
4	.89	1.46	.94	1.61	.94	1.77
5	1.08	1.65	1.14	1.81	1.14	2.17
6	1.34	1.93	1.34	2.21	1.34	2.56
7	1.53	2.21	1.53	2.56	1.69	2.80
8	1.73	2.44	1.73	2.87	1.93	3.19
9	1.94	2.72	1.94	3.07	2.13	3.58
10	2.13	2.91	2.13	3.27	2.36	3.94
11	2.33	3.27	2.41	3.68	2.56	4.33
12	2.53	3.47	2.67	3.98	2.84	4.65
13	2.72	3.66	2.86	4.37	3.03	5.04
14	2.91	4.06	3.06	4.57	3.23	5.43
15	3.11	4.25	3.25	4.76	3.43	5.83
16	3.31	4.65	3.55	5.12	3.62	6.22
17	3.50	4.84	3.75	5.51	3.90	6.54
18	3.84	5.16	3.94	5.91	4.09	6.93
19	4.05	5.35	4.21	6.22	4.29	7.32
20	4.23	5.55	4.41	6.61	4.49	7.91
21	4.53	5.91	4.61	7.01	4.69	8.31
22	4.72	6.30	4.80	7.40	4.88	8.90
24	5.12	6.69	5.20	7.99	5.28	9.69
26	5.51	7.48	5.67	8.50	5.83	10.32
28	5.91	7.87	6.06	9.29	6.22	11.10

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**Table 7.6 Shaft and Housing Shoulder Diameters  
XLS Series Bearings**

Bearing Bore Number	Minimum Shaft Shoulder Diameter S	Maximum Housing Shoulder Diameter H
	Inches	
XLS-1- $\frac{1}{8}$	1.3125	1.9375
XLS-1- $\frac{1}{4}$	1.4375	2.0625
XLS-1- $\frac{3}{4}$	1.9375	2.8125
XLS-1- $\frac{7}{8}$	2.0625	3.0000
XLS-2- $\frac{1}{4}$	2.4375	3.3750
XLS-2- $\frac{3}{8}$	2.5625	3.5625
XLS-2- $\frac{1}{2}$	2.6875	3.6875
XLS-2- $\frac{5}{8}$	2.8125	3.9375
XLS-2- $\frac{3}{4}$	2.9375	3.9375
XLS-2- $\frac{7}{8}$ ❶	3.0625	4.0000
XLS-3	3.1875	4.3125
XLS-3- $\frac{1}{4}$	3.4375	4.5625
XLS-3- $\frac{3}{8}$	3.5625	4.7500
XLS-3- $\frac{1}{2}$	3.7500	4.7500
XLS-3- $\frac{3}{4}$	4.0000	5.0000
XLS-4	4.3750	5.2500
XLS-4- $\frac{1}{8}$	4.5000	5.6250
XLS-4- $\frac{1}{4}$	4.6250	5.6250
XLS-4- $\frac{1}{2}$	4.8750	5.8750
XLS-4- $\frac{3}{4}$	5.1250	6.1250
XLS-5	5.3750	6.6250
XLS-5- $\frac{1}{8}$	5.5000	6.6875
XLS-5- $\frac{1}{2}$	5.8750	7.1250
XLS-6- $\frac{1}{4}$	6.6250	8.1250
XLS-6- $\frac{3}{4}$ ❶	7.1250	8.6250
XLS-7	7.3750	9.1250
XLS-8- $\frac{3}{4}$ ❶	9.1875	11.3750

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## Engineering Information

### 8.0 Radial Internal Clearance and Preload

Ball bearing radial internal clearance is defined as the total radial distance the bearing outer ring can be displaced from a maximum in one direction to a maximum in the opposite direction while holding the inner ring stationary.

Radial contact ball bearings are manufactured with radial internal clearances larger than the running clearance. When the bearing is mounted with a press fit on the shaft or in the housing, the clearance is reduced due to the expansion of the inner ring or contraction of the outer ring.

In some applications where radial and axial play of the rotating machine elements must be kept to a minimum, a small internal clearance is specified so that after mounting, a negative clearance or preload condition exists. Greater than standard internal clearance may be desirable when the bearing is mounted with a press fit on both inner and outer rings, such as is the case when the direction of the load is indeterminate. Greater than standard internal clearance may also be necessary when either ring is mounted with an extra heavy press fit, when thermal expansion of one ring is much greater than that of the other ring, or when the bearing operates under predominately thrust load. NTN-BCA® ball bearings can be manufactured with any of the radial internal clearance ranges given in the following table. For assistance in determining the correct bearing radial internal clearance, consult your NTN Applications Engineering Department.

**Table 8.1 Radial Internal Clearance Values  
For Single Row Radial Contact Ball Bearings**

Bearing Bore Number		Radial Internal Clearance Values in 0.0001"							
		Symbol 2 (C2) Tight		Symbol (none) Normal		Symbol 3 (C3) Loose		Symbol 4 (C4) Extra Loose	
Over	Incl	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
mm		Inches							
2.5	6	0	3	1	5	3	9	—	—
6	10	0	3	1	5	3	9	6	11
10	18	0	3.5	1	7	4.5	10	7	13
18	24	0	4	2	8	5	11	8	14
24	30	0.5	4.5	2	8	5	11	9	16
30	40	0.5	4.5	2.5	8	6	13	11	18
40	50	0.5	4.5	2.5	9	7	14	12	20
50	65	0.5	6	3	11	9	17	15	24
65	80	0.5	6	4	12	10	20	18	28
80	100	0.5	7	4.5	14	12	23	21	33
100	120	1	8	6	16	14	26	24	38
120	140	1	9	7	19	16	32	28	45
140	160	1	9	7	21	18	36	32	51
160	180	1	10	8	24	21	40	36	58
180	200	1	12	10	28	25	46	42	64

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**Table 8.2 Radial Internal Clearance Values  
For Double Row Angular Contact Ball Bearings**

Nominal Bore Diameter		Radial Internal Clearance Values in 0.0001"									
		C <sub>1</sub>		C <sub>2</sub>		Normal		C <sub>3</sub>		C <sub>4</sub>	
Over	Incl	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
mm		Inches									
—	10	3	8	6	12	8	15	15	22	22	30
10	18	3	8	6	12	8	15	15	24	30	40
18	30	3	10	6	12	10	20	20	32	40	55
30	50	3	10	8	14	14	25	25	40	55	75
50	80	3	11	11	17	17	32	32	50	75	95
80	100	3	13	13	22	22	40	40	60	95	120
100	120	3	15	15	30	30	50	50	75	110	140
120	150	3	16	16	33	35	35	55	80	130	170
150	180	3	18	18	35	35	60	60	90	150	200
180	200	3	20	20	40	40	65	65	100	180	240

## Engineering Information

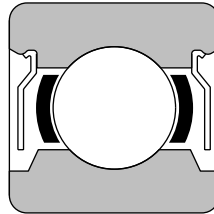
### 9.0 Bearing Closures

#### 9.1 General

In order to extend service life, radial ball bearings must have an adequate supply of lubricant that remains in the bearing and remains clean. The use of seals and/or shields in the bearing makes certain that dust, dirt, moisture, metal chips and other such foreign materials do not penetrate the bearing cavity. In addition to keeping the bearing lubricant clean, seals and shields also help retain grease in the bearing.

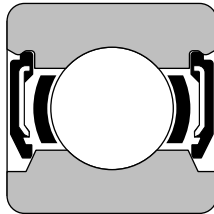
#### 9.2 Seals and Shields for Standard Radial Ball Bearings

The two most common closures used on standard radial ball bearings are a metal shield and a synthetic rubber contact type seal. Each of these types of closures is described below.



**SHIELD**

A bearing shield is a stamped metal washer-like disc. It provides the most economical closure for one or both sides of a radial ball bearing. The shield is crimped into a groove in the outer ring for maximum retention and is non-removable. The clearance between the shield bore and the inner ring recess is held to a minimum to retain the maximum amount of lubricant and to prevent the ingress of large foreign particles.



**SEAL**

Most NTN-BCA® seals are outer ring snap-in, inner ring contact type seals. These seals have been developed as a result of extensive laboratory tests performed by NTN-BCA® and field tests performed by our customers under actual operating conditions.

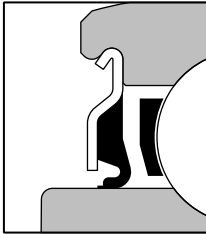
The typical seal is comprised of a synthetic rubber seal lip molded to a stamped steel reinforcing backing ring. The backing ring gives the seal strength and rigidity. The design of the seal lip allows for normal axial movement of the inner ring without impairing the sealing effect. The seal has a thick lip section to provide smooth, constant pressure against the step in the inner ring. The seal is snapped into a groove in the outer ring compressing the rubber and providing a tightly sealed joint.

The standard seal material is a nitrile rubber and will operate effectively at temperatures ranging from -40°F to 225°F making these seals suitable for the large majority of typical applications. Other special environment seals are available if needed. Please consult your NTN Sales Representative for further details.

## Engineering Information

### 9.3 Seals for Ag and Other Harsh Environment Bearings

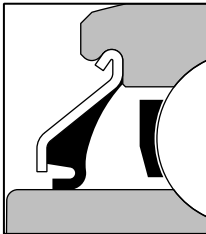
The Vanguard® series of land riding seals are specifically designed for extremely hostile environments. The seals have been successfully applied to a number of different applications.



VANGUARD® "R" SEAL

The Vanguard® "R" single lip seal is designed for bearings where axial space is limited and operating conditions are severe.

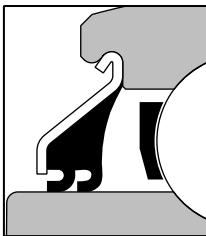
This seal consists of nitrile rubber bonded to a heavy duty steel trash guard. The seal lip rides on the ground inner ring outside diameter to provide superior sealing. The running clearance between the inner ring and the trash guard is held to a minimum to prevent dirt and trash from penetrating the bearing. The seal is crimped into the outer ring and becomes a permanent part of the bearing. The trash guard is chemically treated to resist pitting and corrosion.



VANGUARD® "G" SEAL

The Vanguard® "G" seal is also a single lip land riding seal designed for extremely hostile environments. The Vanguard "G" seal is designed for use on bearings where axial space is plentiful, allowing additional grease capacity.

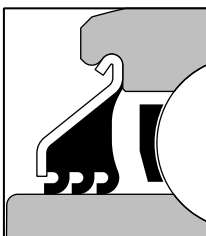
The seal consists of a nitrile rubber seal lip bonded to a heavy duty trash guard. The seal lip rides on the ground inner ring outside diameter to provide superior sealing. The metal trash guard is crimped into the outer ring seal groove and becomes permanently attached to the bearing. The metal trash guard is chemically treated to resist pitting and corrosion.



VANGUARD® "V" SEAL

The Vanguard® "V" seal is a double lip land riding seal designed to have high frictional drag for use in more severe applications running at low to moderate speeds.

The Vanguard® "V" seal consists of two rubber seal lips bonded to a steel trash guard, riding on a ground inner ring outside diameter. The chemically treated metal trash guard is crimped into the outer ring seal groove becoming permanently attached to the bearing.



VANGUARD® "T" SEAL

The Vanguard® "T" seal is a triple lip land riding seal designed for the most severe conditions such as those found on agricultural or construction machinery. Because of its extremely high drag, this seal is limited to low speed applications.

The Vanguard® "T" seal consists of three seal lips bonded to a steel trash guard, riding on a ground inner ring outside diameter. The chemically treated metal trash guard is crimped into the outer ring seal groove becoming permanently attached to the bearing.

## Engineering Information

### 10.0 Limiting Speeds

#### 10.1 General

The maximum permissible operating speed for ball bearings is governed by three primary factors:

- temperature rise
- centrifugal force
- vibration

Limiting speeds for all BCA bearings are shown in the bearing tables. It should be noted however that these limiting speeds are general guidelines and should not be accepted as rigorously defined limits. The catalog limiting speeds assume normal loading for grease or oil lubrication, horizontal mounting, inner ring rotation minimal misalignment and adequate lubrication. Any major variation in any of these areas will cause a reduction in bearing limiting speed.

If a bearing is operated with its outer ring rotating an equivalent inner ring speed must be calculated and compared to the limiting speed data shown in the bearing tables. The method for calculating equivalent inner ring rotational speed is shown as equation 10.1.

$$\text{Equation 10.1} \quad N_{ir} = \frac{\frac{d+D}{2} - d_w \cos \alpha}{\frac{d+D}{2} + d_w \cos \alpha} \times N_{or}$$

- Where:
- $N_{ir}$ : Equivalent Inner Ring rotational speed (rpm)
  - $d$ : Inner Ring bore (inches)
  - $D$ : Outer Ring outside diameter (inches)
  - $d_w$ : Ball diameter (inches)
  - $N_{or}$ : Outer Ring rotational speed (rpm)
  - $\alpha$ : Contact Angle (in most cases zero)

### 11.0 Lubrication

#### 11.1 Lubrication of Rolling Element Bearings

The purpose of the lubricant in the bearing is to prevent metal to metal contact between the rolling elements, bearing raceways and bearing cages, thus minimizing heat generation. In addition, the lubricant in the bearing provides necessary protection against corrosion. A properly lubricated bearing has a thin oil film on the contact surfaces providing the following advantages:

- reduced friction and wear
- heat dissipation
- prolonged bearing life
- prevention of rust from forming on internal components
- protection against foreign particles/elements

For best results the user must select a good quality lubricant, properly design the lubrication type/system for the application, and provide an effective sealing arrangement to protect lubrication from foreign contaminants.

## Engineering Information

### 11.2 Grease Lubrication

Grease lubricants are relatively easy to handle, require the simplest sealing devices, and frequently require a simpler machine design. For these reasons grease is the most widely used form of rolling element bearing lubrication.

#### 11.2.1 Grease Types and Characteristics

Lubricating greases contain either mineral or synthetic base oil. Thickeners and other additives are combined with the base oil to form the end grease product. The properties of a given grease are determined by the base oil type, the thickener and the various additives.

##### 11.2.1.1 Base Oil

There are a number of different base oils used in general purpose bearing greases. Natural mineral oils are commonly used as are synthetic oils such as diester, silicone and fluorocarbon oils. The properties of any grease are primarily determined by the properties of the base oil. Generally, greases with a low viscosity base oil are best suited for low temperatures and high speeds, while greases made from high viscosity base oils are suited for higher temperatures, slower speeds and heavier loads.

##### 11.2.1.2 Thickening Agents

Thickening agents are combined with base oils to maintain the semi-solid consistency of the grease. Thickening agents consist of either metallic soaps or non-soaps. Metallic soap thickeners include lithium, sodium, calcium, calcium complex and aluminum.

Non-soap thickeners are divided into two groups, i.e., organic such as polyurea and fluorocarbon, or in-organic such as silica gel and bentonite. Each thickener type has its own unique characteristics making each one suitable for different conditions.

Characteristics of a grease such as limiting temperature range, mechanical stability and water resistance depend largely on the thickener type used. For example, lithium thickened greases have long been used in applications where water washout is a concern, whereas polyurea greases are known to provide good performance under a wide variety of operating conditions.

General characteristics of various thickener and base oil combinations are shown in Table 11.1. As performance characteristics may vary from one manufacturer to another, it is best to contact a grease manufacturer when selecting a grease.

**Table 11.1** Types and characteristics of greases

Name of grease	Lithium grease		Sodium grease (Fiber grease)	Calcium grease (Cup grease)	Non-Soap Based Grease	
Thickener	Li soap		Na soap	Ca soap	Bentonite, Silica, Urea	
Base oil	Mineral oil	Diester oil	Mineral oil	Minera oil	Mineral Oil	Synthetic Oil
Dropping point °C	170~190	170~190	150~180	80~90	> 250	> 250
Applicable Temperature range °C	-30~+130	-50~+130	-20~+130	-20~+70	-10~+130	-50~+200
Mechanical properties	Excellent	Good	Excellent or Good	Good	Good	Good
Pressure resistance	Good	Good	Good	Good	Good	Good
Water resistance	Excellent	Good	Good	Excellent	Good	Good
Applications	The widest range of application	Excellent low temperature and wear characteristics	Some of the grease is emulsified when mixed in water  Good high temperature resistance	Excellent water resistance, but inferior heat resistance  Low speed and heavy load use	Wide operating temperature range  Long Life greases	

## Engineering Information

### 11.2.2 Required Grease Quantity

The amount of grease required depends heavily upon the application conditions. As a general rule of thumb, however, it is recommended that approximately one third of the bearing free cavity be filled and in cases where an adjacent cavity is used for additional grease, that cavity should be filled no more than 50% full.

Excess grease in the bearing can lead to grease churning and heat generation. If a bearing is over filled, the heat will not dissipate and the grease life will be shortened.

As the speed of rotation increases, the quantity of grease recommended generally decreases. On the contrary, in very severe application conditions such as heavy loads and extreme contamination, more grease is generally recommended.

### 11.2.3 Grease Relubrication Interval

Many NTN-BCA® bearings are factory pre-filled with grease and are intended to be greased for life. Relubrication of these bearings is generally not recommended.

On the other hand, many applications require an occasional replenishment of grease. In those instances, the interval for relubrication is often questioned. Because bearings are subjected to varying degrees of load, speed, temperature, contamination, etc., it is very difficult to provide definitive relubrication intervals. The best relubrication interval is often determined by frequent inspection and monitoring of the bearing and subsequent modifications to the existing interval. When regreasing a bearing it is recommended that the bearing be rotating to guard against over-filling.

## 11.3 Oil Lubrication

Oils used for ball bearing lubrication should be highly refined petroleum products with additives depending upon the service conditions. Neither animal oils nor vegetable oils are stable enough to be considered suitable for bearing lubrication, although substantial research is currently being conducted.

Generally, oil lubrication is better suited for high speed and high temperature applications. Oil is especially effective in these applications as it is used to dissipate the heat generated by the bearing or carry it away from the bearing.

### 11.3.1 Methods of Applying Oil Lubrication

There are four commonly used methods for applying oil lubrication. Each method has its advantages and disadvantages. The four common methods of oil lubrication are:

- Oil Bath
- Oil Splash
- Drip Feed
- Circulating Oil

#### 11.3.1.1 Oil Bath Lubrication

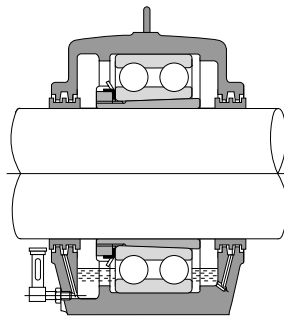


Figure 11.1 Oil Bath Lubrication

Oil bath lubrication is one of the more common methods of oil lubrication. It is most commonly applied to horizontal applications. Control of the oil level is important to ensure that the oil is not churned, causing it to dramatically rise in temperature and possibly foam. Generally it is recommended that the oil level in an oil bath system be maintained at approximately the center of the lowest rolling element in the bearing. Figure 11.1 illustrates an oil bath system.

## Engineering Information

### 11.3.1.2 Oil Splash Lubrication

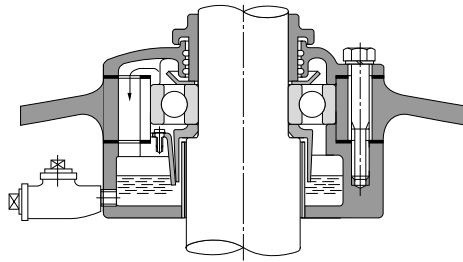


Figure 11.2 Oil Splash System

In an oil splash system, the bearing is not directly submerged in the oil. Instead an impeller or similar device is mounted onto the shaft which splashes the oil onto the bearing. The oil splash system can be used for moderately high rotational speeds. Figure 11.2 illustrates an oil splash system.

### 11.3.1.3 Drip Oil Lubrication

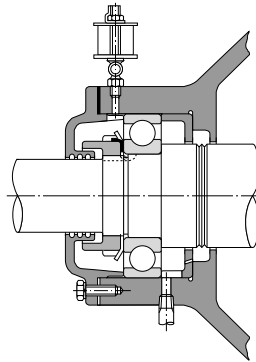


Figure 11.3 Drip Lubrication System

Drip lubrication is used for relatively high speed, high load applications. An oiler is mounted on the housing above the bearing allowing oil to drip down on the bearing. As the oil hits the rotating parts it turns to an oil mist. Figure 11.3 illustrates a drip lubrication system.

### 11.3.1.4 Circulating Oil Lubrication

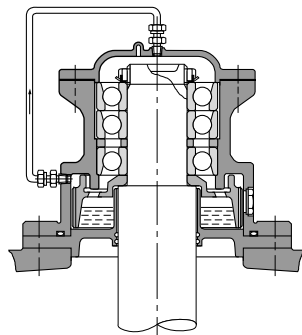


Figure 11.4 Circulating Oil System

Circulating oil systems are suitable for high speed applications where bearing heat generation is high. In this type of system, the oil supply is centrally located. The principal advantage of this type of system is that the oil can be run through coolers and filters after running through the bearing. Keeping the oil cool and clean is paramount to prolonging oil and ultimately bearing life.

For this method of lubrication to be effective, it is imperative that the oil be evacuated from the bearing chamber after passing through the bearing. To facilitate this evacuation, oil inlets and outlets must be provided on opposite sides of the bearing. If the oil drain cannot be made large enough to drain the oil via the forces of gravity, it must be forced out. Figure 11.4 illustrates a circulating oil system on a vertical shaft application.

## Engineering Information

### 11.4 Selection of Grease or Oil

The determination of grease or oil as the proper bearing lubricant depends on many factors, but is mostly linked to bearing rotational speed and economics. Oil is generally suitable for any bearing applications but is required when speeds are very high. The drawback to oil lubrication is the design of the machine incorporating the bearing is generally more complicated and costly if oil is the selected lubricant. Oil and grease lubrication guidelines are shown below.

**Oil lubrication is suitable for:**

- all speeds, but is required for extremely high speeds
- elevated temperatures exist requiring the lubricant to be carried away and cooled
- contaminated oil conditions where filtering of the lubricant is required
- closed systems where the oil is required to lubricate other frictional contact components
- applications requiring precisely controlled quantities of lubrication

**Grease lubrication is suitable for:**

- extremely low to relatively high speeds
- moderate operating temperatures
- applications requiring a barrier against foreign particles
- applications where economics limits the intricacy of the machine design
- applications where simple lubricated for life bearings are acceptable