

THIN SECTION BALL BEARING ENGINEERING DATA

The methods, equations, and technical data presented in this section allow the user to select the correct bearings and estimate their performance for a wide range of applications. For applications with severe or unusual operating conditions, RBC is prepared to provide an in-depth analysis and recommend the most suitable bearing arrangement.

Where standard bearings cannot be used, RBC can meet the application requirements with a special bearing design specifically tailored for optimum performance. Questions concerning information in this section should be directed to the appropriate RBC Aerospace Bearings sales engineer.

Capacity and Fatigue Life of Ball Bearings

The basic dynamic radial load rating, C, or “dynamic capacity,” for a ball bearing is the calculated, constant radial load at which 90% of a group of apparently identical bearings with stationary outer rings can statistically endure 10^6 revolutions of the inner ring. ANSI/ABMA Standard 9 with correction factors for race curvatures was used to calculate the catalog ratings.

The dynamic thrust and dynamic moment load ratings are also shown in the product tables. The ratings shown are a guide for the maximum loads under which these bearings should be operated with either pure thrust or pure moment loading. Thrust ratings are 2.5 to 3.0 times the radial ratings depending on the bearing type and cross-section. These load ratings are not additive. For combined radial and thrust loads, an equivalent radial load is to be calculated.

The basic static load rating, C_0 , or “static capacity,” is that uniformly distributed load, which produces a maximum theoretical contact stress of 609,000 psi. At this contact stress, permanent deformation of ball and raceway occurs. This deformation is approximately .0001% of the ball diameter.

The rating life, L_{10} , is a statistical measure of the life which 90% of a large group of apparently identical ball bearings will achieve or exceed. For a single bearing, L_{10} also refers to the life associated with 90% reliability. Median life, L_{50} , is the life that 50% of the group of ball bearings will achieve or exceed. Median life is approximately five times the rating life.

The relationship between rating life, load rating, and load is:

$$L_{10} = (C/P)^3 \text{ with } L_{10} = \text{rating life (} 10^6 \text{ rev)}$$

$$C = \text{basic dynamic radial load rating (lbf)}$$

$$P = \text{equivalent radial load (lbf)}$$

To obtain the rating life in hours, use:

$$L_{10 \text{ hrs}} = 16667/N * (C/P)^3 \text{ with } N = \text{speed (rpm)}$$

The equivalent radial load is defined as:

$$P = XF_r + YF_a \quad \text{with} \quad \begin{array}{l} F_r = \text{radial load (lbf)} \\ F_a = \text{axial load (lbf)} \\ X - \text{see below} \\ Y - \text{see below} \end{array}$$

Radial Contact Bearing Calculations

For radial contact bearings calculate P with $X = 1$ and $Y = 0$. Then recalculate P with $X = 0.56$ and $Y =$ (see chart below). Use the larger value of P to determine L_{10} life.

$\frac{F_a}{nd^2}$	Y
25	2.30
50	1.99
100	1.71
150	1.55
200	1.45
300	1.31
500	1.15
750	1.04
1000	1.00

n = number of balls
 d = diameter of balls (in.)

Angular or 4-Point Contact Bearing Calculations*

For angular contact and 4-point contact bearings calculate P with X = 1.0 and Y = 0. Then recalculate P with X = 0.39 and Y = 0.76. Use the larger value of P to determine L₁₀ life.

The equations are valid in the range of approximately 100 hrs to 100,000 hrs of life. Extreme loads or speeds may result in a shorter life; while in less demanding applications, metal fatigue may never affect bearing service life.

*Capacity and fatigue life information is based on ANSI/ABMA Standard 9-1990 published by: The American Bearing Manufacturers Association, Inc., 1200 19th Street, NW, Suite 300, Washington, DC 20036-2401

Adjustment Factors for Rating Life

If a bearing design and operation deviates significantly from normal, it may be necessary to use additional factors to estimate the fatigue life L_n.

$$L_n = a_1 * a_2 * a_3 * L_{10hrs}$$

- with a₁ = reliability factor
- a₂ = material and processing factor
- a₃ = application factor

Reliability Factor a₁

Reliability is the percentage of a group of apparently identical ball bearings that is expected to attain or exceed a specified life. For an individual bearing it is the probability that the bearing will attain or exceed a specified life. Typical bearing fatigue life is calculated for 90% reliability. The life adjustment factors for other reliability numbers are shown below.

Reliability %	L _n	Reliability Factor a ₁
90	L ₁₀	1.00
95	L ₅	.62
96	L ₄	.53
97	L ₃	.44
98	L ₂	.33
99	L ₁	.21

Material Factor a₂

For standard bearings, the material factor a₂ is equal to 1.00. Factor a₂ is determined by material processing, forming methods, heat treatment, and other manufacturing methods. Some commonly used material factors are listed below:

Material, Condition	a ₂ max
52100, Air melt	1.00
52100, Vacuum degassed	1.50
52100, Air melt and TDC Plate	2.00
52100, Vacuum melt, (CEVM)	3.00
440C, Air melt	1.00
440C, Vacuum melt (CEVM)	3.00
M50, Vacuum melt (CEVM)	5.00
M50, Vacuum re-melt (VIM-VAR)	8.00

Application Factor a₃

The application factor a₃ is equal to 1.0 for most applications. Unusual or extreme conditions in certain applications such as low speed, shock loading, vibration, and extreme temperature may lower the application factor to 0.50. Contact your RBC Aerospace Sales Engineer for help in determining this factor for special applications.

Load and Speed Limitations

The load ratings shown in the product tables are not additive. For combined simultaneous loading, an equivalent radial or thrust load must be considered. In general, C-Type bearings are designed for radial loading applications; moderate thrust and/or moment loading may be applied in combination with radial loading. For thrust loading applications use the A-Type bearing; any radial loading should only be applied in combination with thrust loading. X-Type bearings are primarily for reversing thrust and moment loading, pure radial loading should not be applied.

The limiting speeds shown in the product tables are based on standard lubrication. The unsealed bearing speeds are calculated assuming the bearings are lubricated with MIL-PRF-8085. Limiting speeds for sealed bearings are calculated assuming the bearings are lubricated with MIL-PRF-23827 grease. If bearings are lubricated with alternate oils or greases, new limiting speeds must be calculated, see page 95.

OPERATING CONDITIONS

Lubrication

Lubricants serve a number of very important purposes in ball bearings, including:

- protecting bearing surfaces from corrosion
- reducing rolling and sliding friction
- preventing metal-to-metal contact between balls and raceway
- providing a barrier against external contaminants (grease)
- removing heat (oil)

Lack of lubrication or inadequate lubrication is the most common cause of bearing failure.

Standard RBC thin section ball bearings are lubricated with either oil or grease. The unsealed bearings, the K series, are thoroughly coated in MIL-PRF-8085 oil and drained of excess. Sealed bearings are lubricated with MIL-PRF-23827 grease. The external surfaces of sealed bearings are lightly coated with the same grease for corrosion resistance. Additional lubricants are also available. An RBC Aerospace Sales Engineer can help select the appropriate lubricant for special applications.

Temperature

Standard RBC thin section ball bearings can operate at temperatures from -65°F to +250°F. Temperatures up to 350°F can be reached if the bearings are temperature stabilized. By the use of special materials RBC can provide bearings for operation to 900°F. Contact the RBC Aerospace Bearings sales engineer for recommendations on bearings operating above 250°F.

Limiting Speed

The limiting speed of a bearing is dependent upon a number of different factors including bearing size, bearing type, ball separator design, lubrication and loading. The limiting speeds for the bearings shown in this catalog are determined using the following:

$$N = \frac{1000 * k}{E} \text{ with } N = \text{Speed (RPM)}$$

$$E = \frac{D+B}{2} \text{ (Bearing pitch diameter)}$$

$k = \text{constant, see table below}$

Bearing Type	Load Condition	k Value	
		Grease	Oil
C or A	Radial or Thrust	16	20
X	Thrust	10	12
X	Radial, Combined Radial & Thrust, or Moment	3	4

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The “k” values shown give the maximum speeds at which a typical thin section ball bearing can operate. It is recommended that operating speeds of large diameter bearings in a given series be reduced up to 40% of the calculated rating to avoid high bearing temperatures. Speed ratings can also be impacted by load conditions, lubrication, alignment, and ambient temperature. All of these factors must be considered when designing thin section ball bearings into your application.

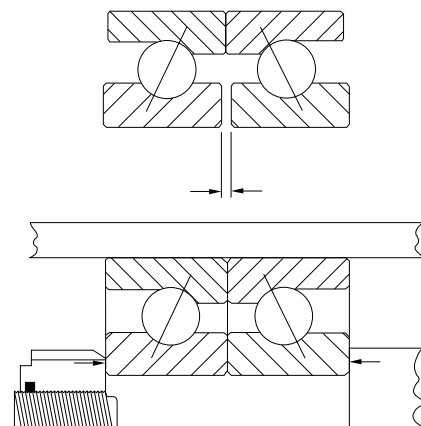
DUPLEX PAIRS AND AXIAL PRE-LOADING

Duplex Pairs

Duplex bearings are a pair of angular contact RBC thin section ball bearings specially ground for use as a matched set. A duplexed pair can be used to provide accurate shaft location, to increase capacity or to increase stiffness of the bearing assembly. A duplex pair of RBC thin section ball bearings is ground so that when mounted using recommended fits, there will be no internal clearance in the bearings. There are three basic mounting methods to accommodate different loading requirements:

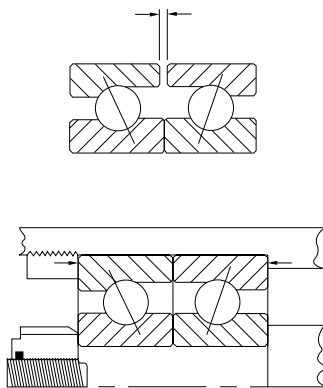
- Back-to-Back (DB), B-Type
- Face-to-Face (DF), F-Type
- Tandem (DT), T-Type

Back-to-Back, DB
B-Type



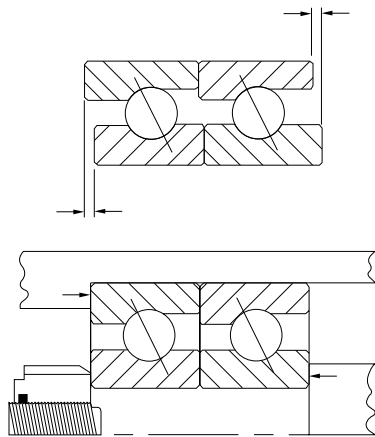
- Heavy radial loads
- Combined thrust and radial loads
- Reversing thrust loads
- Excellent rigidity
- Moment loads

Face-to-Face, DF
F-Type



- Heavy radial loads
- Combined thrust and radial loads
- Reversing thrust load
- Moment loads

Tandem, DT
T-Type



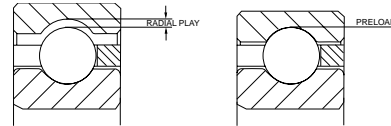
- High one-direction thrust loads
- Minimum axial shaft deflection
- Heavy radial loads

Axial Pre-loading

Standard duplex bearings are ground so that there will be a light axial pre-load induced on the bearing at nominal conditions. In some applications increased bearing stiffness may be required. In these cases the duplex grinding can be done such that a heavier axial load is induced in the mounted bearing. This load can be increased or decreased to meet the requirements of a particular application. Consult an RBC Aerospace Bearings sales engineer for special requirements.

Radial Play

Radial play (diametral clearance) is the distance the inner ring can be moved radially from one extreme position to the other. Standard RBC thin section ball bearings are manufactured with enough radial play that some clearance remains after the bearing is properly installed.



When there is negative radial play (diametral preload) there is interference rather than clearance between the balls and the races. As the interference increases, the friction, stiffness and torque also increase. RBC thin section ball bearings can be manufactured with customer specified diametral preload or clearance. Consult an RBC Aerospace Bearings sales engineer for design assistance.

Radial and Axial Runout

Radial runout of RBC thin section ball bearings is a measurement of the thickness variation of the bearing rings. The outer ring is measured from the ball path to the outer diameter of the ring, the inner ring is measured from the ball path to the bore. Radial runout is defined as the wall thickness variation of the rotating ring.

Axial runout is measured from the ball path to the face of the bearing rings. The variation in thickness measured is the axial runout.

TOLERANCES

Precision Grades

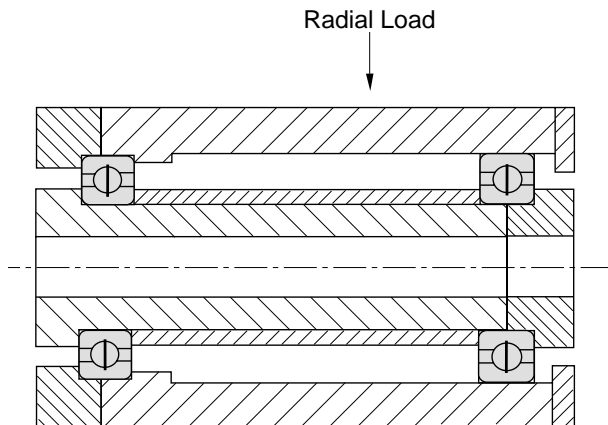
RBC thin section ball bearings are available in four precision grades. RBC precision classes 0, 3, 4, and 6 correspond to ABMA ABEC grades 1F, 3F, 5F, and 7F respectively. The tolerances for the bearing bores, outer diameters, radial runouts, axial runouts, and radial plays are shown in the Tolerance Tables on pages 102 – 104.

Shaft and Housing Fits

Proper shaft and housing fits are critical to the successful operation of a thin section ball bearing. The internal clearance of the bearing will be reduced proportionally by an interference fit. In addition, the roundness of the shaft and housing will directly affect the roundness of the inner and outer ring raceways. For most applications, the inner ring is rotating and the load is stationary with respect to the outer ring. In this circumstance, a light press fit onto the shaft is recommended. The recommended shaft and housing fits are shown in the Tolerance Tables on pages 102 – 104.

MOUNTING ARRANGEMENTS

When selecting a mounting arrangement for RBC thin section ball bearings, you must first consider the loading condition. A duplex pair of angular contact bearings may be used for combined loading, moment loading, or heavy thrust loading. Combination A and C-Type, A and X-Type, or C and X-Type bearings are common mounting arrangements. Two X-Type bearings should never be mounted on the same shaft. There may be many different bearing arrangements for carrying the same load. Some typical mounting arrangements are shown below.

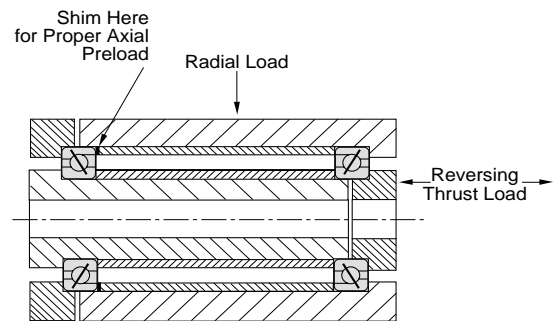


Heavy Radial Loads

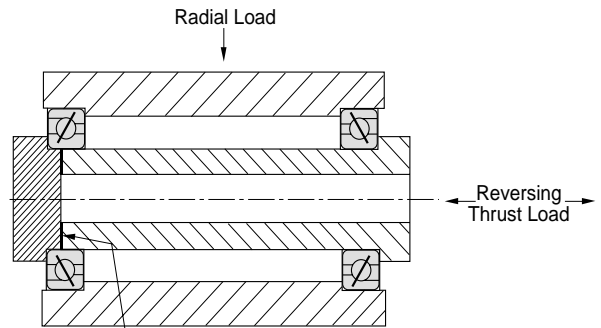
The C-Type bearing is designed primarily for heavy radial loads. Two bearings can be installed on the same shaft as shown. By axially fixing one bearing and allowing the other to float, this configuration allows differential expansion between the housing and shaft, such as caused by temperature difference, without adding axial stress to the bearings. Although the C-Type bearing is designed for radial loads, they can withstand moderate thrust, moment, and reversing loads.

Reversing Loads

The duplex pair of A-Type bearings offers several configurations. For reversing loads, either back-to-back, B-Type, or face-to-face, F-Type, should be used. The F-Type mounting method demonstrates reversing thrust load. Combined radial and thrust loads are shown on the B-Type configuration. Both of these methods can be used for heavy radial loads, combined thrust, and radial loads, or moment loads.



F-Type Configuration

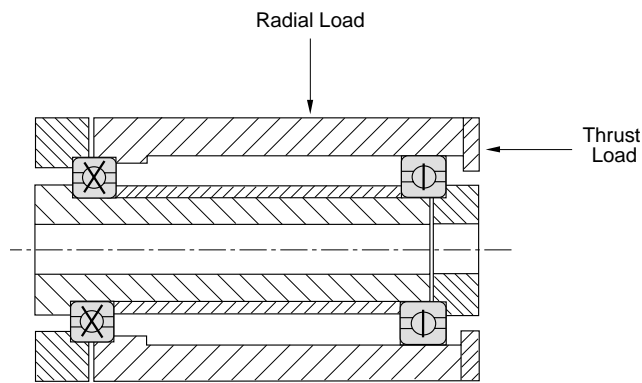
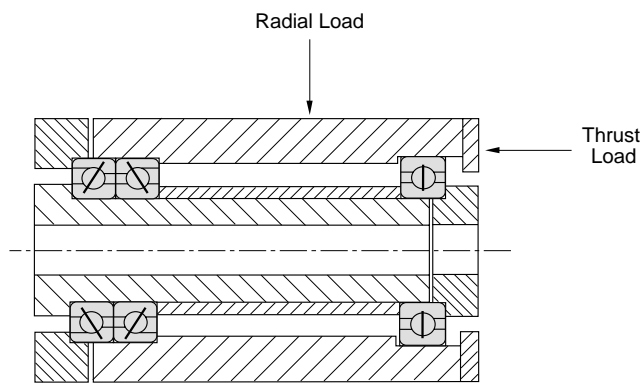


B-Type Configuration

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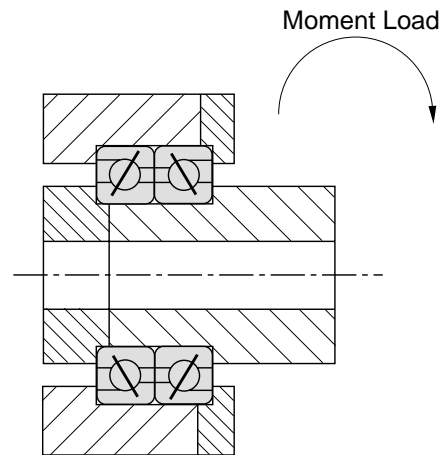
Heavy Combined Loading

For heavy combined loading, other special mounting arrangements may be employed. As shown in the top drawing, a duplex pair of A-Type bearings can be used with a floating C-Type bearing. In this configuration, the A-Type bearings will carry the thrust load and part of the radial load while the C-Type carries only radial load. An X-Type bearing can replace the duplex pair of A-Type bearings to carry lower thrust loads as shown in the second drawing.

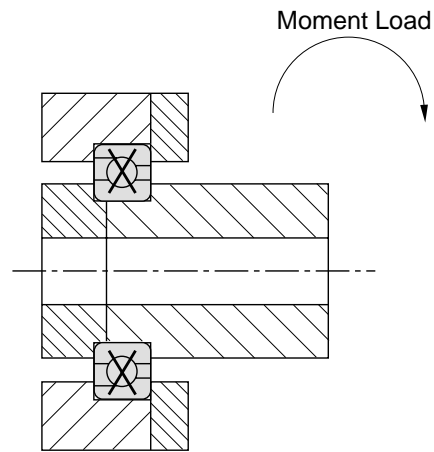


Heavy Combined Loading or Moment Loading

Alternate mountings for heavy combined loading or moment loading are shown below. A duplex pair of B-Type bearings resists high thrust, radial, and moment loads. An X-Type bearing may replace the duplex pair in less heavily loaded applications for weight, space, and cost savings.



B-Type Configuration



Single Bearing X-Type Configuration

CUSTOM FEATURES

RBC manufactures many custom bearings designed to optimize bearing performance for specific applications. Special features include changes in radial play, lubricants, materials, pre-loading and design. Contact an RBC Aerospace Bearings sales engineer for your custom bearing needs.

There are many design options available to solve difficult application problems.

Materials

The standard bearings shown in the catalog have SAE 52100 steel rings and balls. RBC thin section ball bearings can be manufactured from other specialty bearing steels to provide corrosion resistance, high temperature capability, alternative load capacity, or chemical compatibility.

Rings— RBC has manufactured thin section ball bearings from SAE CRES 440C to provide corrosion resistance. As an alternative to stainless steel rings, the entire surface of the rings can be plated with nodular thin dense chrome (TDC). This plating, which meets AMS 2438, achieves a molecular bond that will not flake, peel, or separate from the base material. The TDC plate has a hardness of HRC 70 - 78 and can withstand temperatures well beyond the range of the base material.

Special RBC thin section ball bearings have been manufactured from aluminum, 300 series stainless steel, 17-4 stainless steel, and other metals.

Balls— Some special ball materials available include 440C CRES, 300 Series stainless steel, silicon nitride, and M-50 steel.

Lubrication

Many different lubricants are available from RBC for special applications. Greases that are designed specifically for high speed, low torque, water resistance, high temperature, oscillatory motion, and food machinery can be provided. Additional lubricants, such as dry film, are suitable for use in vacuums and space applications.

Sealing

Standard seals for thin section ball bearings are molded from elastomers. PTFE seals, fiber glass reinforced PTFE seals, stainless steel shields, and many other options are available for low torque and other special applications.

Radial Play

The radial play (diametral clearance) of a thin section ball bearing will need to be predetermined if mounting fits other than those recommended are used. Special radial play may be required for a temperature differential across the bearing, for housing and shaft materials that have different coefficients of thermal expansion, or to change operating characteristics of the bearing. Radial pre-loaded bearings are measured to meet bore and O.D. tolerances prior to pre-load.

Pre-loading of Duplex Bearings

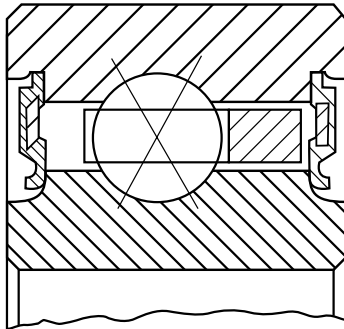
Standard duplex bearings are ground so that there will be a light axial pre-load induced on the bearing at nominal conditions. In some applications increased bearing stiffness may be required. In these cases the duplex grinding can be done such that a heavier axial load is induced in the mounted bearing. This load can be increased or decreased to meet the requirements of a particular application. Consult your RBC Aerospace Bearings sales engineer for special requirements.

Mounting Features

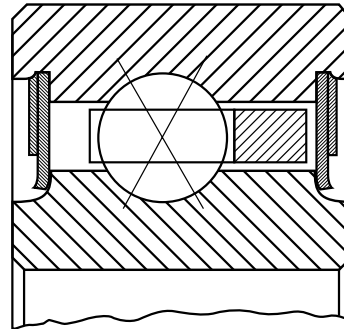
Mounting features, such as flanges, anti-rotation tabs, and mounting holes can be incorporated on the inner and outer rings. Mating parts, such as gears and housings, may be integrated into the bearing rings for improved performance and cost.

ELASTOMER MOLDED SEALS VS. PTFE/SS300 SEALS

Typical elastomer molded design



Typical PTFE/SS300 design

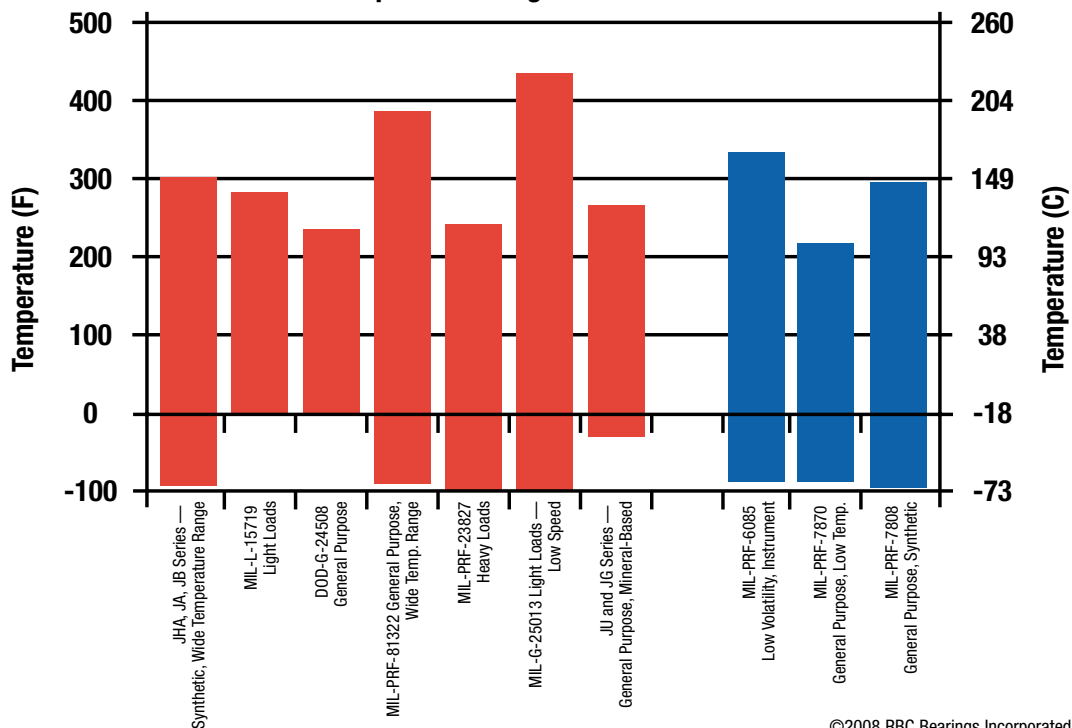


Many molded seals used in bearings are made out of nitrile (molded rubber per MIL-R-6855). The material has a relatively high coefficient of friction. In order to meet low torque bearing requirements, seal fit-up during installation must be adjusted to minimize contact pressure on the sealing surfaces — reducing torque by reducing sealing effectiveness. The inherent variability in the seal molding process can further aggravate these issues. Over time, torque fluctuations are nearly inevitable since seals may reset or the amount of lube between the seal and the sealing surface may change. Based on these performance characteristics, molded seals are often marginal and unreliable solutions for torque sensitive applications.

RBC's solution is a combination seal-shield design. The seal is made from either pure PTFE or glass fiber reinforced PTFE. PTFE is chemically inert, has a very low coefficient of friction (inherent lubricity), and provides the widest operating temperature range of any sealing material. The seal is held in place and shielded with a stainless steel (300 series) flat ring. The seal drag torque in this design is minimal, predictable, and consistent over time.

RBC invariably recommends this design for all low torque or torque sensitive applications that require sealing. RBC can readily retrofit problematic molded seal designs with a PTFE/300SS optimized solution.

Temperature Ranges for Lubrications



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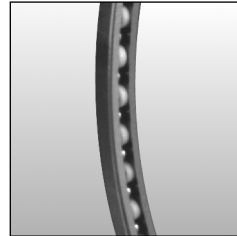
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Separators

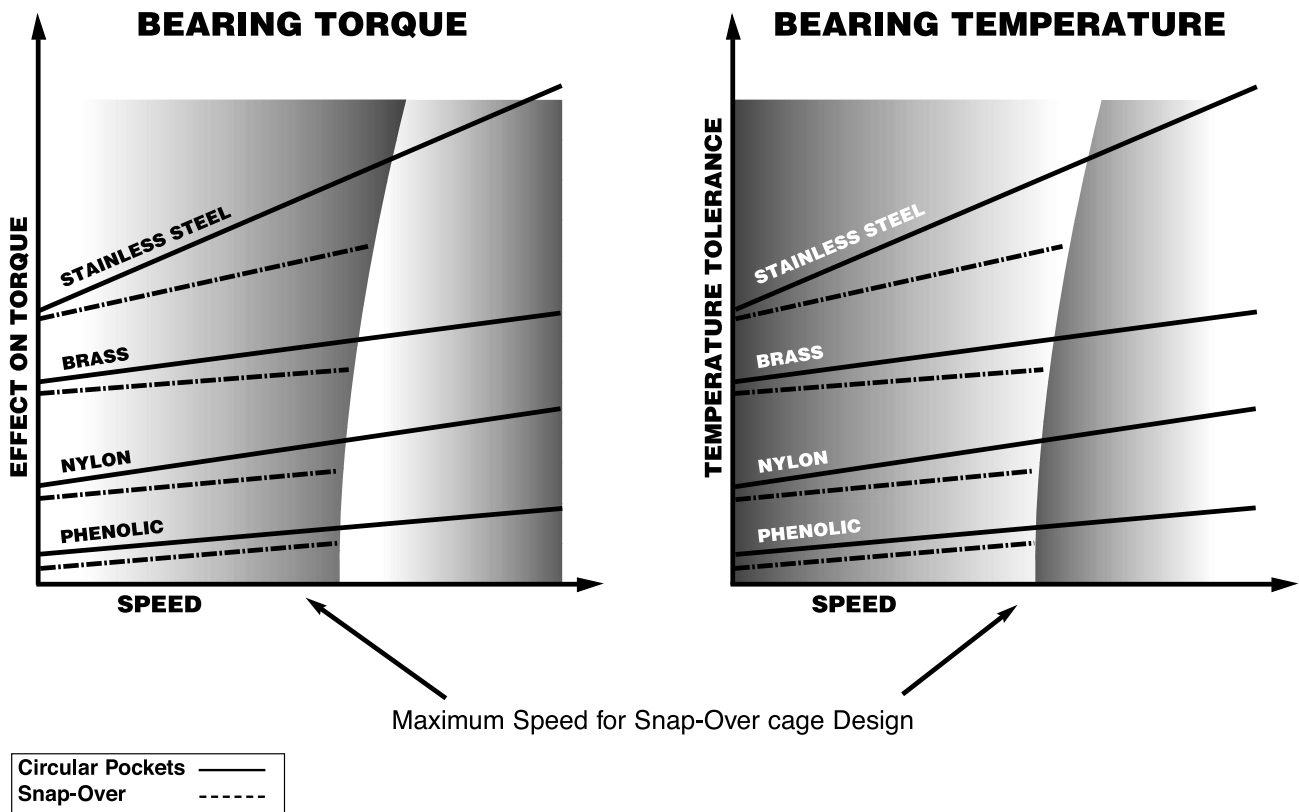
Standard RBC thin section ball bearings, KA through KG and JU series, are manufactured with brass separators. The KAA series contains nylon separators. The A-Type bearings contain one-piece circular pocket separators, while the C and X-Types have snap-over separators. The four basic separator materials are brass, nylon, phenolic, and stainless steel.

The graph below schematically illustrates the effects of cage design and material on bearing performance. For example, the one-piece circular pocket design may reach roughly two times the speed of the snap-over design. Likewise, a brass separator design will generate more torque and withstand higher temperatures than a

phenolic separator. Exact speed limits depend on bearing size, bearing type, lubrication and loading. Specific material advantages and limitations are illustrated below. For assistance in selecting the appropriate separator for special applications, contact your RBC Aerospace Bearings sales engineer.



Schematic Illustration of Effects of Cage Design and Material on Bearing Torque, Speed and Temperature.



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