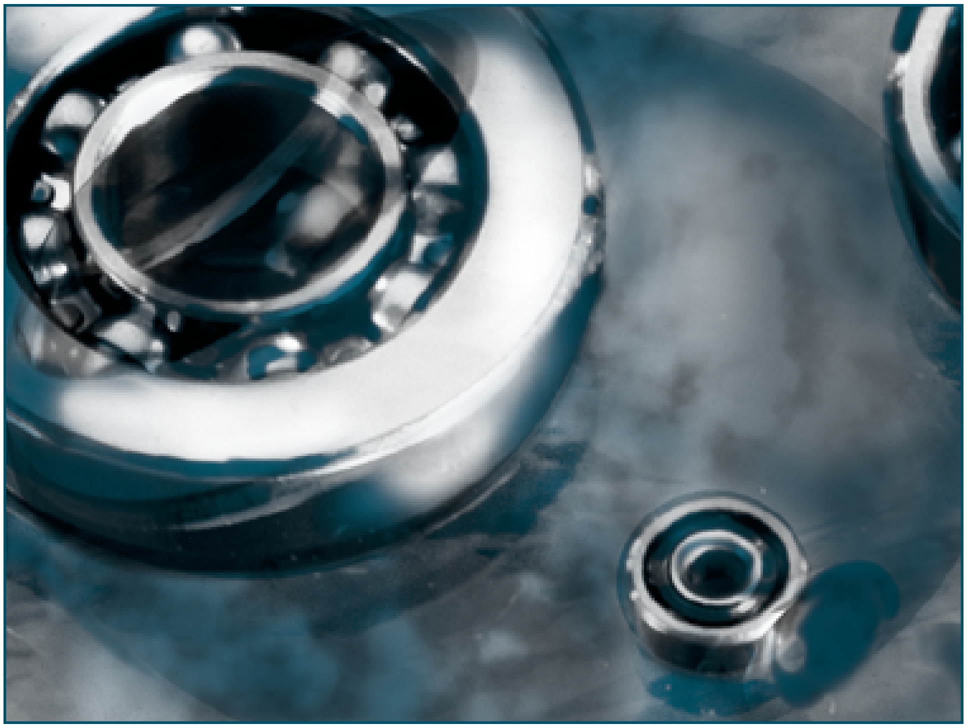
The information contained in this section is provided to assist you in the selection of the proper ball bearing product for your application. Early involvement of NHBB sales engineering is recommended to assure that the product chosen meets your critical requirements for performance, life and cost.



Engineering Services

Computer Design & Analysis

NHBB utilizes computerized design capabilities which allow complex ball bearing applications to be examined and analyzed. These capabilities ensure the ultra-precision ball bearing you select will meet your specific requirements for performance, life and cost.

Engineering Test Laboratory

NHBB maintains a fully-equipped Engineering Test Laboratory which allows us to confirm the performance characteristics of our ball bearing designs. The lab contains a full complement of commercially available equipment, as well as specialized equipment developed by NHBB and precisely tailored for specific test requirements, such as our high speed bearing vibration tester (patent pending).

Materials Laboratory

NHBB Materials Laboratory has been specifically designed and equipped to perform complex chemical, metallurgical and visual analysis of the many component parts in ball bearings. The lab can also be used to perform wear and failure studies on customer bearings.

Metallurgical studies are done with a metallograph and micro-hardness testers. The metallograph performs micro-structure photography at magnifications from 25 to 2000 times. Micro-hardness testers, using diamond indentors under loads from 1 to 10,000 grams, are used to test material hardness.

During laboratory wear studies, ball bearings are disassembled and examined under a laminar flow hood. All findings can be recorded permanently with a 200X photo-microscope for analysis and future reference.

Functional Tests for Ball Bearings

NHBB has devised a series of rigidly monitored tests which measure starting and running torques, as well as vibration or "noise" levels. During testing, a ball bearing is normally mounted with a thrust load applied.

Starting torque is a measure of the effort required to initiate bearing rotation under a thrust load and can be a critical factor in applications requiring multiple, low-speed start/stop movements.

Running torque is a measure of the effort required to maintain rotation, under a certain load, after rotation has been initiated. NHBB measures running torque values at standard speeds of 1/2 to 2 RPM with applied thrust loads of 75 or 400 grams. The test is fully monitored with results permanently recorded onto a strip chart. This chart can also be analyzed for various ball bearing characteristics such as surface finish, contamination, brinelling and overall geometry. Testing running torque is time consuming and primarily used on a sample basis or for performing diagnostic analysis. Both torque tests meet MIL-STD-206 requirements.

NHBB has developed Anderon Meter "noise ratings" to assure the consistent performance of every bearing we manufacture. After assembly, Anderon Meters are used to test for bearing noise and vibration under a controlled load and speed.

Please consult NHBB Engineering for recommendations on the many specialized tests we can perform.

Materials

The characteristics of alloys and their heat treatment play a major role in the ultimate performance of any ball bearing. Environmental conditions and performance requirements help determine the appropriate choice of bearing materials. The traditional materials used in ball bearings are 440C stainless steel and 52100 chrome steel. These materials are heat treated to achieve optimum hardness and dimensional stability and are suitable for most conditions. For unique or extreme applications, NHBB can offer hybrid ball bearings, consisting of steel rings and silicon nitride balls. These are typically used in applications involving ultra high speeds or high stiffness requirements.

The properties of 440C balls can also be enhanced by a titanium carbide coating.

Standard Materials

AISI 440C

1% C, 17% Cr, .5% Mo

A hardened, stainless steel suitable for applications which require corrosion resistance at room to mid-hot temperature range; the standard choice for a wide variety of military and commercial applications.

SAE 52100

1% C, 1.45% Cr

Chrome steel used for specific ball bearing applications where corrosion resistance is not a major concern.

Standard Materials

Material	Specification	Melt Method	Attributes	Room Temp. Hardness (Rc)		Stabilization Temp. Limit (°F)
				Balls	Rings	
440C	AMS 5618	CEVM*	Premium Quality. Very Low Impurity Level.	58-65	58-62	350°
52100	AMS 6444	CEVM*	Premium Quality. Low Impurity Level.	60-67	60-64	350°

*Consumable Electrode Vacuum Melted

Alternate Ball Material

CERBEC® Bearing Components

Silicon Nitride

An extremely hard non-metallic material suitable for speeds up to 2 million dN with reduced skidding. This material is corrosion resistant, 60% lighter than steel and non-magnetic. Silicon nitride has a modulus of elasticity 50% greater than steel, therefore, it increases bearing rigidity. It is virtually inert and thus it resists corrosion and galling.

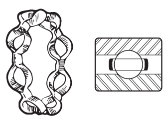
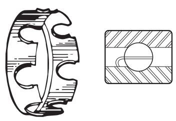
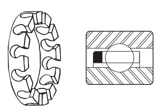
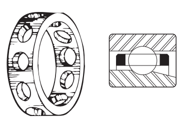
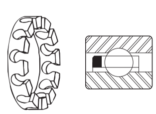
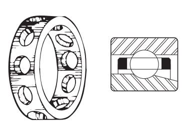
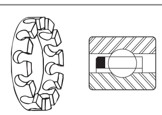
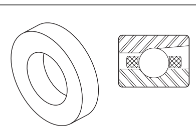
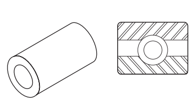
Alternate Ball Material

Material	Specification	Attributes	Room Temp. Hardness (Rc)
Silicon Nitride	CERBEC Silicon Nitride	Extended life, lower torque, light weight, higher stiffness	>78

Cages

The most common bearing cages are shown below. In some cases, such as high-load applications, a full complement design may be the best choice. For operating speed, please refer to the Nmax/fn values in the product tables and the multiplier table on page 39. NHBB can also supply specially designed cages to meet your specific requirements. If any doubt, NHBB should be contacted for optimum cage selection.

Basic Cage Capabilities

Description	+	Design	Material	Max. Speed (ref.) dN**	Operating Temp Max.	Comments	Typical Applications
Ribbon Two-Piece Stamped, Crimped	R		A.I.S.I. 305 Steel	150,000	900°F	Superior Starting Torque Low Cost	General Purpose
Crown One-Piece Stamped	H		A.I.S.I. 410 Steel	150,000	900°F	Higher Speed Capability Than Ribbon Retainer Low Cost	General Purpose
Crown One-Piece Machined	KB		Phenolic-Paper Base	1,200,000	250°F	High Speed Impregnated with Oil	Medical, Machine Tools, High Speed Motors
	KC		Phenolic-Linen Base				
Full Type, One-Piece Machined	M4		Polyamide-imide	2,000,000	500°F	High Speed Capability Requires Lubrication Fully Autoclavable	Medical/Dental High Temperature
Crown, One-Piece Machined	M5		Polyamide-imide	1,200,000	500°F	High Speed Capability Requires Lubrication Fully Autoclavable	Medical/Dental High Temperature
Full Type, One-Piece Machined	KN		Phenolic-Paper Base	2,000,000	250°F	High Speed, Quiet Running, Angular Contact Bearing Only, Porous Material Impregnated with Oil	Machine Tool Spindles High Speed Motors
	KM		Phenolic-Linen Base				
Crown One-Piece Machined	T1*		PGM High Temp.	Consult with Factory	575°F	Self-Lubricating	Low-Speed Light Load
			PGM		375°F		
Toroid	TT		PTFE	5,000	450°F	Low Torque, Low Speed, Angular Contact Bearing Only	Slow Rotation, Oscillating Motion Cryogenic
Slug	SL		PTFE	1,000	450°F	Low Torque, Low Speed,	Gimbal Assembly Slow Rotation Low Torque Oscillating Motion

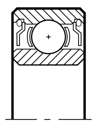
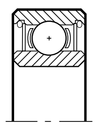
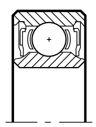
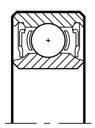
+ Typical Part Number Designation   *Controlled by assigned special design number   **dN is bore (in millimeters) x RPM
Additional cage designs and materials available. Please contact Applications Engineering for assistance.

Shield & Seal Types

Shields and seals are protective closures which retain lubricants and assist in preventing contaminants from reaching internal surfaces. In torque-sensitive applications, it may be advantageous to use shields rather than seals because there are no contacting surfaces to create drag. The following chart illustrates the more common types of shields and seals.

Consideration should be given to the compatibility of cage and shield type designs to allow for appropriate clearance. Consult with factory for availability.

Shield and Seal Types

Description	Type	Design	Material	Operating Temp Max.
Shield—Removable with snap wire. Minimal clearance. Most popular.	Z		Stainless Steel 300 Series	600°F.
Seal with snap wire. Provide minimal clearance to light contact resulting in low torque.	L		Glass-reinforced PTFE	400°F.
Seal—Excellent sealing characteristics.	D		Buna-N Bonded to Steel Insert	250°F.
Seal—Excellent sealing characteristics. High cost.	D1		Viton Bonded to Steel Insert	400°F.

Radial and Axial Play, Raceway Curvature, Contact Angle

When a ball bearing is running under a load, force is transmitted from one bearing ring to the other through the balls. Since the contact area between each ball and the rings is relatively small, moderate loads can produce stresses of tens, even hundreds of thousands of pounds per square inch. These internal stresses have a significant impact on bearing life and performance. Thus the internal geometry of a bearing—its radial play, raceway curvature and contact angle—must be carefully chosen so loads can be distributed for optimal performance.

Radial and Axial Play

Most ball bearings are assembled in such a way that a slight amount of looseness exists between the balls and the raceways. This looseness is referred to as radial play and axial play. Radial play is the maximum distance that one bearing ring can be displaced with respect to the other, in a direction perpendicular to the bearing axis when the bearing is in an unmounted state. Axial play, or end play, is the maximum relative displacement, in a direction parallel to the bearing axis, between the two rings of an unmounted ball bearing.

Since radial play and axial play are both consequences of the same degree of looseness between the components, they bear a mutual dependence. Yet their values are usually quite different in magnitude. Radial play can often vary between .0002 and .0020, while axial play may range from .001 to .010. The suggested radial play ranges for typical applications should always be consulted when a device is in the initial design phase.

Suggested Radial Play

Typical Application	Suggested Radial Play*
Small Precision High Speed Electric Motors	.0005 to .0008
Tape Guides, Belt Guides, Low Speed	.0002 to .0005
Tape Guides, Belt Guides, High Speed	.0005 to .0008
Gyro Gimbals, Horizontal Axis	.0002 to .0005
Gyro Gimbals, Vertical Axis	.0005 to .0008
Precision Gear Trains, Low Speed Electric Motors, Synchros and Servos	.0002 to .0005
Gyro Spin Bearings, Ultra-High Speed Turbines and Spindles	Consult factory

*Measurement in inches.

In most ball bearing applications, radial play is functionally more critical than axial play. While radial play has become the standard purchasing specification, you may also specify axial play requirements. Keep in mind, however, the values of radial play and axial play for any given bearing design are mathematically interdependent, and that radial play is affected by any interference fit between the shaft and bearing I.D. or between the housing and bearing O.D., as shown on page 53. Since the important condition is the actual radial play remaining after assembly of the complete device, the radial play specification for the bearing must be modified in accordance with the discussion in the mounting and coding section on page 51.

Standard Radial Play Ranges

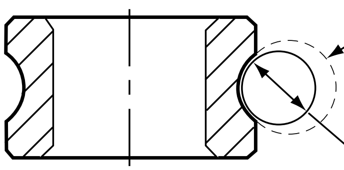
Description	Radial Play Range*	NHBB Code
Tight	.0001 to .0003	P13
Normal	.0002 to .0005	P25
Loose	.0005 to .0008	P58
Extra Loose	.0008 to .0011	P811

*Measurement in inches.
Non-standard ranges may be specified.

Radial and Axial Play, Raceway Curvature, Contact Angle

Raceway Curvature

Raceway curvature is the ratio of the raceway radius to ball diameter. Raceway curvature values typically are either 52 to 54 percent or 57 percent. The lower 52 to 54 percent curvature implies close ball-to-raceway conformity and is useful in applications where heavy loads are encountered. The higher 57 percent curvature is more suitable for torque sensitive applications.



Formulas for Radial Play, Axial Play and Contact Angle

Radial Play

$$P_D = 2BD_b\,(1 - \cos\alpha_0)$$

$$P_D = 2BD_b - \sqrt{(2BD_b)^2 - P_E^2}$$

Axial Play

$$P_E = 2BD_b \sin\alpha_0$$

$$P_E = \sqrt{4BD_bP_D - P_D^2}$$

Contact Angle

$$\alpha_0 = \cos^{-1}\frac{2BD_b - P_D}{2BD_b}$$

$$\alpha_0 = \sin^{-1}\frac{P_E}{2BD_b}$$

P_D = Radial play

P_E = Axial play

α_0 = Contact angle

B = Total curvature = $(f_i + f_o - 1)$

f_i = Inner ring curvature*

f_o = Outer ring curvature*

D_b = Ball diameter

* Expressed as the ratio of raceway radius to ball diameter.

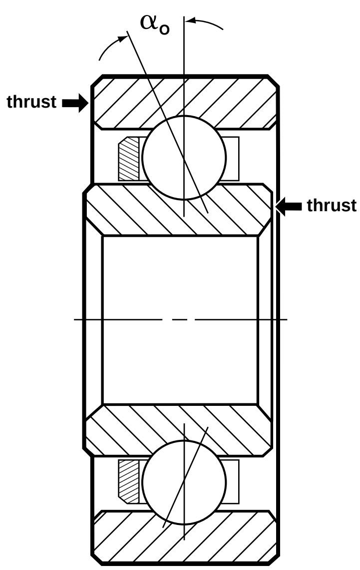
Radial and Axial Play, Raceway Curvature, Contact Angle

Contact Angle

Contact angle is the angle between a plane perpendicular to the ball bearing axis and a line joining the two points where the ball makes contact with the inner and outer raceways. The initial contact angle of the bearing is directly related to radial play—the higher the radial play, the higher the contact angle. The "Table of Contact Angles" as shown gives nominal values under no load.

For support of pure radial loads, a low contact angle is desirable; where thrust loading is predominant, a higher contact angle is recommended.

Contact Angle α_o



The contact angle of thrust-loaded bearings provides an indication of ball position inside the raceways. When a thrust load is applied to a ball bearing, the balls will move away from the median planes of the raceways and assume positions somewhere between the deepest portions of the raceways and their edges.

Table of Contact Angles α_o

Ball Size D_b	Radial Play Code		
	P25	P58	P811
.025	18°	24 1/2°	30°
1/32 & 0.8mm	16 1/2°	22°	27°
1mm	14 1/2°	20°	24°
3/64	14°	18°	21°
1/16	12°	16°	19°
3/32	9 1/2°	13°	15 1/2°
1/8	12 1/2°	17°	20°
9/64	12°	16°	19 1/2°
5/32	11°	15°	18 1/2°
3/16	10°	14°	16 1/2°

The contact angle is given for the mean radial play of the range shown i.e., for P25 (.0002 to .0005)—contact angle is given for .00035. Contact angle is affected by raceway curvature. For your specific application consult with factory.

Lubrication

Lubricant Types

Oil is the basic lubricant for ball bearings. NHBB offers both petroleum-based and synthetic oils such as diesters, silicone polymers and fluorinated compounds. In general, diesters have better low temperature properties, lower volatility and better temperature/viscosity characteristics than petroleum-based oils. Silicones and fluorinated compounds possess even lower volatility and wider temperature/viscosity properties.

Grease is an oil to which a thickener has been added to prevent migration from the lubrication site, resulting in longer life. It is used in situations where frequent replenishment of the lubricant is undesirable or impossible. The operative properties of grease depend almost wholly on the choice of base oil. Other factors being equal, the use of grease instead of oil results in higher starting and running torques and can limit the bearing to lower speeds.

Solid film lubricants are any non-fluids used to prevent wear and reduce friction. They can range from simple sacrificial cages to graphite powder and ion sputtering. Each type must be engineered for the specific application.

Solid film lubricants have definite advantages. They are very useful in areas of temperature extremes, vacuum, radiation, pressure or harsh environments where conventional lubricants would fail. In addition, these lubricants do not deteriorate in storage.

Oils and Base Fluids

Petroleum Lubricants:

- Excellent load carrying abilities
- Moderate temperature range (–25° to 250°F)
- Greases with petroleum oil bases have high dN capability (recommended for light to heavy loads and moderate to high speeds)

Synthetic Lubricants:

- Wide temperature range (–65° to 350°F)
- Resist oxidation
- Less film strength than petroleum oils

Silicone Lubricants:

- Wide temperature range (–100° to 400°F)
- Less film strength than diesters
- Tend to migrate

Perfluorinated Polyether:

- Wide temperature range (–112° to 400°F)
- Stable at high temperatures
- Chemically inert
- Low vapor pressure (10^{-9} Torr)

Lubrication

Lubrication Methods

Centrifuging an oil-lubricated bearing removes excess oil and leaves only a very thin film on all surfaces. This method is used on very low torque bearings and can be specified for critical applications.

Vacuum impregnation, used with ball bearings containing porous cages, forces lubricant into the pores, using the cage as an oil reservoir. When this method is used with a greased bearing, its purpose is to prevent the cage material from leaching oil from the lubricant. Normally, the base oil of the grease is used in the cage to prevent incompatibility.

Grease packing approximately 1/4 to 1/3 of a ball bearing's internal free volume is one of the most common methods of lubrication. Grease quantity can be controlled by the use of special lubrication equipment.

Grease plating consists of mixing a quantity of grease and solvent to the desired consistency, lubricating the bearing with this mixture, then evaporating the solvent at a moderate temperature, leaving a thin film of grease on raceways and balls.

Operating Speed

To determine whether a particular bearing will operate satisfactorily at the required speed, multiply that bearing's value (Nmax/fn) by the proper factor taken from the fn vs Cage table shown. Note that the table takes into account lubricant and cage type. When petroleum or synthetic ester oils are used, the maximum speed Nmax is dictated by the ball cage material and design or centrifugal ball loads rather than by the lubricant.

For full ball complement types, the listed Nmax values apply regardless of lubricant type or whether the inner ring or outer ring rotates. For speed limit values Nmax, the Nmax/fn values shown in the product listings must be multiplied by the fn values tabulated above.

Table of fn vs Cage, Lubricant Types and Ring Rotating

	Metal Cage		Phenolic or Polyamide-imide			
	2-Piece or Crown Type		Crown Type		Full Section Type	
Lubricant / Ring Rotating	Inner	Outer	Inner	Outer	Inner	Outer
Petroleum Oil	1.0	0.8	2.0	1.2	4.0	2.4
Synthetic Oil	1.0	0.8	2.0	1.2	4.0	2.4
Silicone Oil	0.8	0.7	0.8	0.7	0.8	0.7
Non-Channeling Grease	1.0	0.6	1.6	1.0	1.6	1.0
Channeling Grease	1.0	0.8	2.0	1.2	2.4	1.6
Silicone Grease	0.8	0.7	0.8	0.7	0.8	0.7

Speed Factor

The maximum usable operating speed of a grease lubricant is dependent on the type of base oil. The speed factor is a function of the bore of the bearing (d) in millimeters (mm) and the speed of the bearing (N) in revolutions per minute (RPM) where:

dN = d (bearing bore, mm) x N (RPM)

Type	dN	Temperature Range °F (°C)
Petroleum	600,000	-25 to +250 (-32 to +121)
Diester	400,000	-65 to +350 (-54 to +177)
Silicone	200,000	-100 to +400 (-73 to +204)
Perfluorinated Polyether	200,000	-112 to +400 (-80 to +204)

Lubrication

Lubricant Specifications

We have included a table of Commercial and Military Lubricants and their recommended uses. When ball bearings are ordered without a specified lubricant, it is the policy of NHBB to lubricate with MIL-L-6085 oil.

Company standard lubricants are LO1 Winsor Lube L-245X oil and LG68 Royco 27 grease. The standard quantity of oil varies with bearing size, but is approximately one drop (3–6mg) per bearing up to R-2 size and two drops (6–12mg) for larger sizes. The standard quantity of grease is 30% ±5% of the bearing's internal free volume.

Lubrication

Code	Brand Name	Basic Type	Operating Temp.˚F	Uses
LO1	ANDERSON OIL CO. WINSOR L-245X (MIL-L-6085)	Synthetic Oil	-65 to +300	Light general purpose instrument oil
LO2	NUODEX ANDEROL 401D (MIL-L-6085)	Synthetic Oil	-65 to +300	Light general purpose instrument oil
LY115	DUPONT Krytox 143AC	Fluorinated Oil	-30 to +550	High temperature stability good lubricity properties
LG20	EXXON Beacon 325	Synthetic Grease	-65 to +250	General purpose grease
LG68	ROYAL Royco 27 (MIL-G-23827)	Synthetic Grease	-100 to +275	Corrosion resistance, heavy loads, high speed
LY17	NYE Rheotemp 500	Synthetic (Non-silicone) Grease	-65 to +350	Specialty lube. High speed/high temp Inhibits oxidation. Anti-wear protection
LY48	MOBIL MOBIL 28 (MIL-G-81322)	Synthetic Hydrocarbon Grease	-65 to +350	Wide temperature range, good low temperature torque
LY75	CHEVRON SRI-2	Mineral Grease	-20 to +350	Longer life under high speed/high temp Water/salt water resistance
LY101	DUPONT Krytox 240AC (MIL-G-27617)	Fluorinated Grease	-30 to +550	High temperature stability with good lubricity properties
LY121	KYODO SRL	Synthetic Grease	-40 to +300	Low noise and low torque applications
LY328	CASTROL Braycote Micronic 601EF	Perfluorinated Polyether Grease	-112 to +400	Hostile chemical environment Space applications
LY332	ROYAL Royco 13 (MIL-G-25013)	Silicone Grease	-100 to +450	Light loads, high temperature Water resistance
LF27	DICRONITE Dicronite DL-5	Modified Tungsten Disulfide Dry Film	-350 to +1000	Wear resistant, inert & insoluble non-toxic, anti-corrosive, unaffected by radiation

Preload and Duplex Ball Bearings

Ball bearings are preloaded for a variety of reasons:

- To eliminate radial and axial looseness
- To reduce operating noise
- To improve positioning accuracy
- To reduce repetitive runout
- To reduce the possibility of damage from vibratory loading
- To increase life and axial capacity
- To increase stiffness

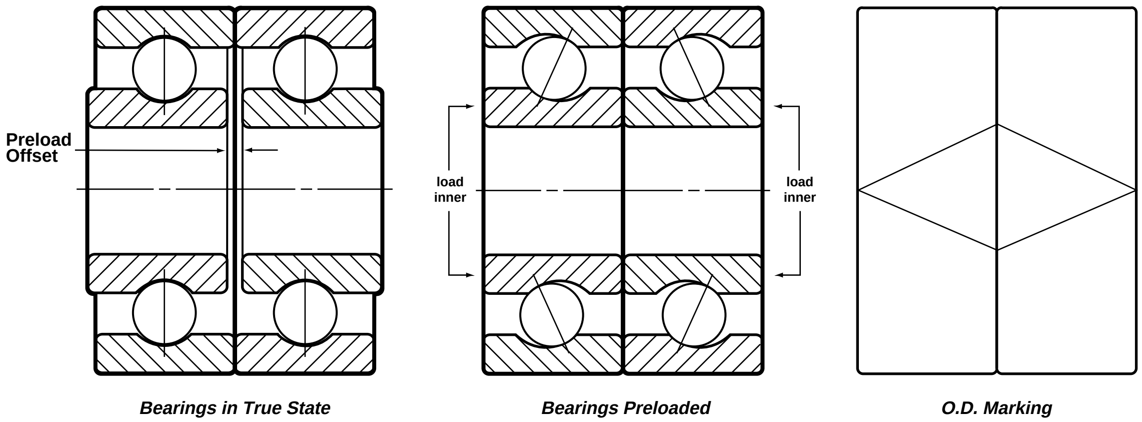
There are essentially two ways to preload a ball bearing, either by using a spring or through a solid stack of parts.

Spring preloading can consist of a coil spring or a wavy washer which applies a force against the inner or outer ring of the non-interference fitted bearing in the assembly.

Since in a spring the load is fairly consistent over a wide range of compressed length, the use of a spring for preloading eliminates the need for holding tight location tolerances on machined parts. For example, retaining rings can be used in the spindle assembly, thus saving the cost of a locating shoulder, shims or threaded members. Normally a spring would not be used where the assembly must withstand reversing thrust loads.

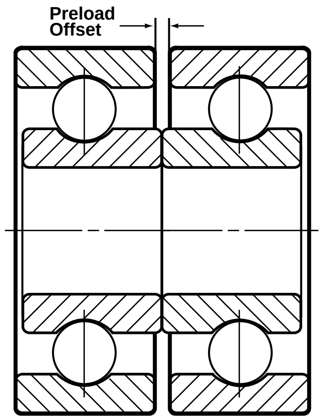
A solid stack method may be used when precise location control is required. For example, as in a precision motor, the use of built-in preload is suggested. Ball bearings with built-in preload are often referred to as duplex ball bearings. When the set of bearings is assembled, the thrust load needed to make the adjacent faces of the rings contact becomes the desired preload. Built-in preload helps satisfy the requirements of increased axial and radial stiffness and deflection control.

There are three methods of mounting preloaded duplex bearings: back-to-back, face-to-face and tandem.

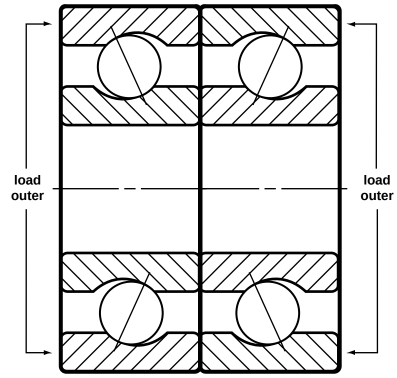


When a back-to-back (DB) duplex pair is mounted, the outer rings abut and the inner rings are drawn together, providing maximum stiffness.

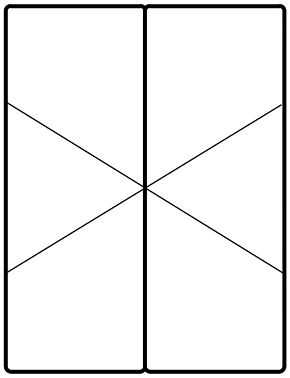
Preload and Duplex Ball Bearings



Bearings in True State

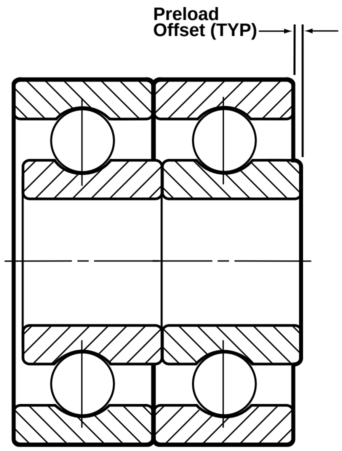


Bearings Preloaded

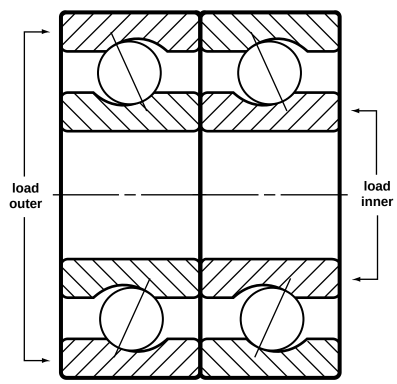


O.D. Marking

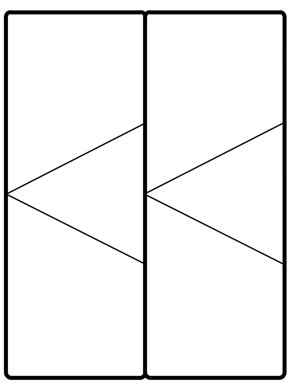
When face-to-face (DF) duplex pairs are mounted, the inner rings abut and the outer rings are drawn together, providing a higher radial and axial stiffness and accommodation of misalignment.



Bearings in True State



Bearings Preloaded



O.D. Marking

With tandem (DT) pairs, both inner and outer rings abut and are capable of sharing a thrust load, providing increased thrust capacity.

NHBB can provide assistance in selecting the appropriate preload specifications for your application.

Load Ratings and Bearing Life

Static Load Ratings

The static load rating (C_o) given in the product listings (pages 10-29) is the radial load which a non-rotating bearing will support without damage. In evaluating static load conditions, any forces exerted during assembly and test must be considered along with vibration and impact loads sustained during handling, test, shipment and assembly.

Dynamic Load Ratings

Dynamic loading (C) includes built-in preload, weight supported members and the effect of any accelerations due to vibration or motion changes. The dynamic load rating (C) for a radial or angular contact ball bearing is a calculated, constant radial load which a group of apparently identical bearings can theoretically endure for a rating life of one million revolutions. The dynamic load rating is a reference value only; a base value rating life of one million revolutions has been chosen for ease of calculation. The dynamic load rating values (C) given in the product listings (pages 10–29) include the effects of race-to-ball conformity and are in accordance with ABMA Standard #12.

Rating Life

The rating life (L_{10}) of a group of apparently identical ball bearings is the life in millions of revolutions that 90% of the group will complete or exceed. For a single bearing, L_{10} also refers to the life associated with 90% reliability.

The magnitude of the rating life, L_{10}, in millions of revolutions for ball bearing application is: $L_{10} = (C/P_E)^3$

The method of computing design life (L) and the nomographs (pages 46-50) are also in conformance with industry standards, with allowance for the effects of curvature on the equivalent radial load resulting from the application of thrust load.

Life calculations can be significantly affected by many factors such as the material or the lubricant. Miniature and instrument ball bearings are normally made of either AISI 440C Stainless Steel or SAE 52100 Chrome Alloy Steel.

Life Modifiers

NHBB recommends that the load rating published for 52100 be reduced by 20% for 440C. This is a conservative approach to insure that the bearing capacity is not exceeded under the most adverse conditions. This is incorporated in the a_2 modifier as shown. The table below provides selected modifiers for calculating failure rates down to 1% (L_1).

Table of Reliability
Material Life Modifier a_2

Required Reliability—%	Ln	Value of a_2	
		52100	440C
90	L_{10}	1.00	0.50
95	L_5	0.62	0.31
96	L_4	0.53	0.27
97	L_3	0.44	0.22
98	L_2	0.33	0.17
99	L_1	0.21	0.11

Load Ratings and Bearing Life

Elastohydrodynamics (EHD Effect)

The presence of a thin film of oil at the mutually contacting ball-to-raceway interface enhances the load capacity of a ball bearing. The lubricant life modifier nomograph (page 50) includes the effect of the elastohydrodynamic lubricant film and can be used to assist in lubricant selection.

Other Life Adjustments

Seldom are loads ideally applied. The conventional rating life often has to be modified due to application abnormalities, intentional or unknown. The following conditions have the practical effect of modifying the ideal, theoretical rating life (L_{10}).

- Vibration and/or shock-impact loads
- Angular misalignment
- Oscillatory duty
- High-speed effects
- Operation at elevated temperatures
- Fits
- Internal design

While it is difficult to provide the exact effect upon life under any of these conditions, NHBB can provide bearing life estimates based on semi-empirical data to help you forecast bearing life for your application.

Lubricant Life

In many instances a bearing's effective life is governed by the lubricant's life. This is usually the case for applications involving very light loads and/or very slow speeds. In such instances, the conventional fatigue life calculated will be unrealistically high. The lubricant's ability to provide sufficient film strength is affected by:

- Quantity and condition of the lubricant in the bearing
- Environmental conditions (e.g. ambient temperature, area cleanliness)
- The load-speed cycle

Specialized oils and greases are available which exhibit favorable performance characteristics over an extended period.

Load Ratings and Bearing Life

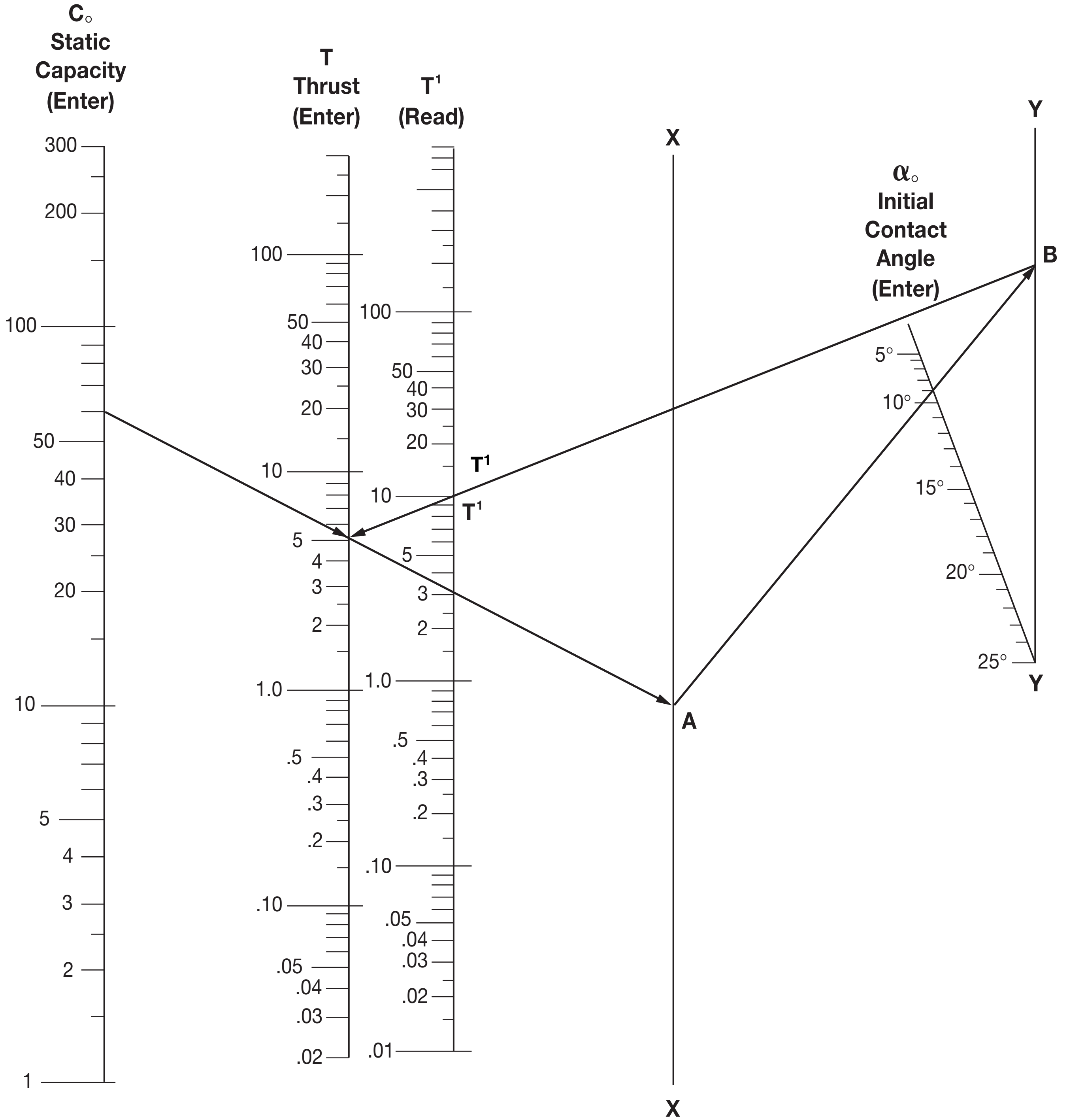
Calculation of Fatigue Life

While miniature and instrument bearings may fail from causes other than fatigue, the fatigue life should be calculated to ensure against failure. To calculate fatigue life, follow the procedure in the table below.

Fatigue Life

Step	Item/Operation	Symbol	Pounds and Inches	
			Obtain from	Example
Given	Radial Load Thrust Load Speed	R T N	Given Given Given	2 lbs. 5 lbs. 15,000 RPM
1 2 3 4 5 6	Obtain lubricant viscosity (consult with factory) Select bearing Read dynamic load rating Read static load rating Read ball size Select radial play range	V C C_o D_b 	— page 10 page 10 page 35	15 cs. SSR-3 140 lbs. 59 lbs. 3/32" P25
7	Obtain initial contact angle using D_b and table	α_o	page 37	9.5°
8	Obtain T^1 from T^1 nomograph using C_o, T and α_o above	T^1	page 46	9.5 lbs.
9	Obtain R^1 from R^1 nomograph using α_o above	R^1	page 48	0.95 lbs.
10	Obtain PE where $PE = T^1 + R^1$ or $PE = R$ whichever is greater	PE	9.5 + 0.95	10.45 lbs.
11	Obtain L_{B10} from B10 life nomograph (number of revolutions or hours) using C and PE above	L_{B10}	page 49	2700 hrs.
12	Obtain lubricant life modifier from lubricant effect nomograph using C, T + R, V and N above	a_1	page 50	1.5
13	Obtain reliability life modifier (a_2) from the table for L_{B10}	a_2	page 43	0.50
14	Obtain design life L where $L = a_1\ a_2\ L_{B10}$	L	1.5 x 0.5 x 2700	2000 hrs.

T1 Nomograph (Lbs or Kg) for Ball Size less than 1/8"

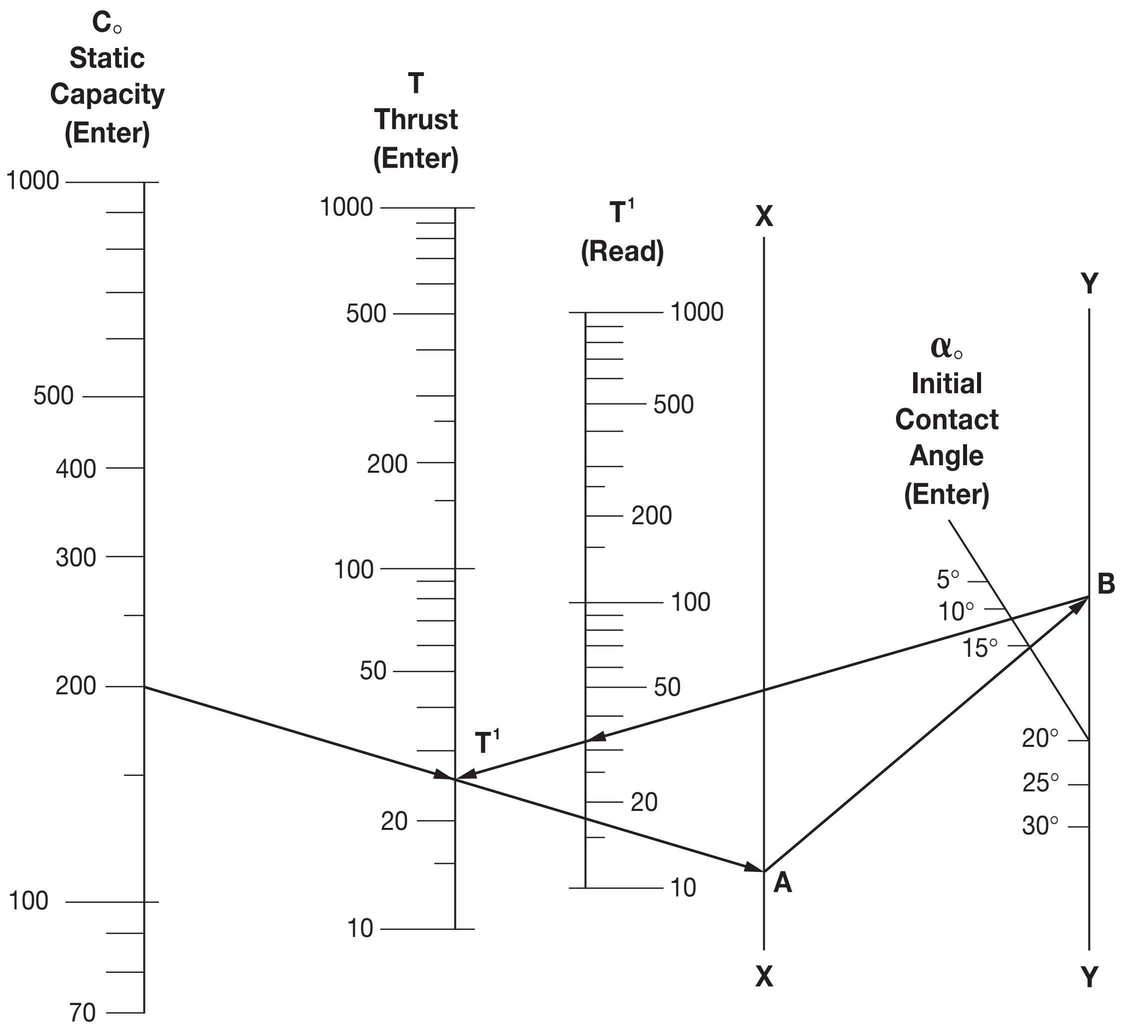


Example: Given C_o = 59 Lbs.
T = 5Lbs.
α_o = 9.5°
Answer: T^1 = 9.5 Lbs.

To Find T^1:

1. Strike a line from C_o (59) thru T (5) to the line X-X (Pt. A).
2. Strike a line from Pt. A thru the α_o (9.5°) to the Y-Y (Pt. B).
3. Strike a line from Pt. B to T (5).
4. Read T^1 = 9.5 Lbs.

T1 Nomograph (Lbs or Kg) for Ball Size 1/8" and Larger

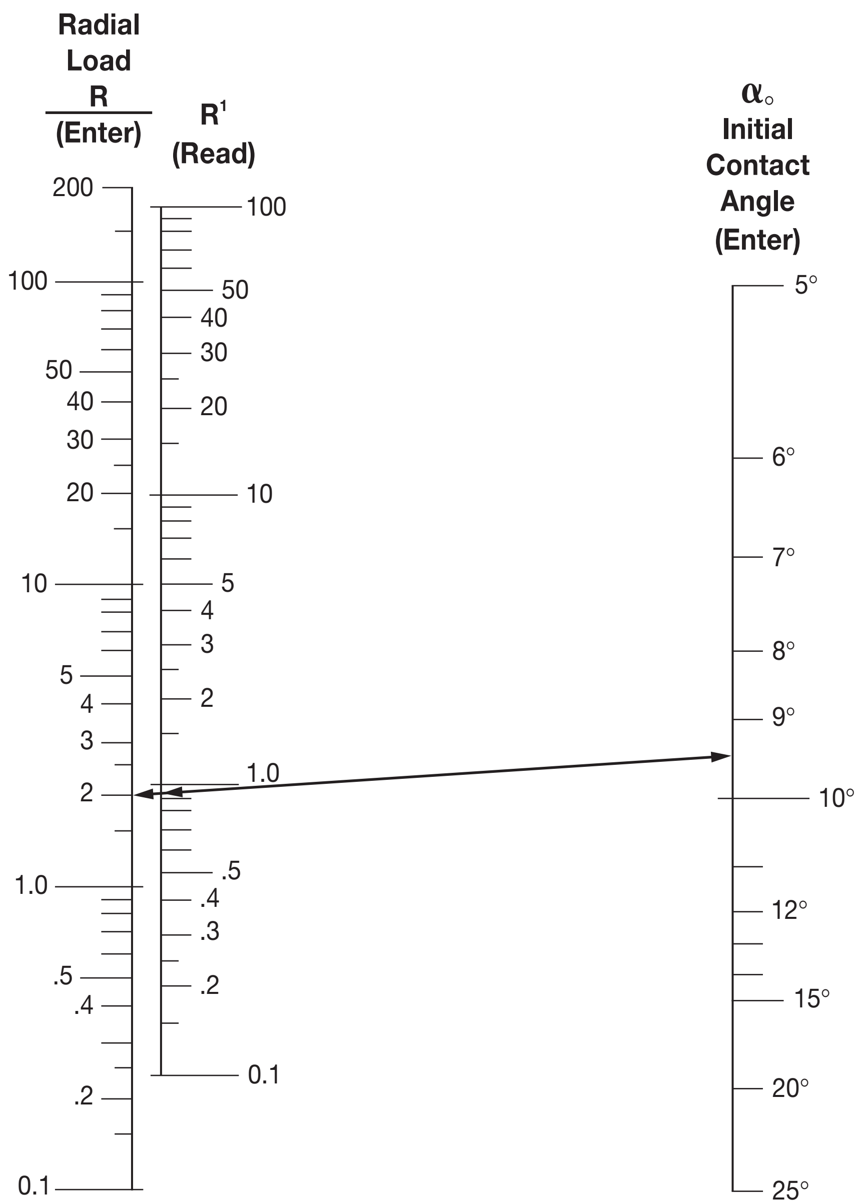


Example: Given C_o = 200 Lbs.
T = 25 Lbs.
α_o = 15°
Answer: T^1 = 32 Lbs.

To Find T^1:

1. Strike a line from C_o (200) thru T (25) to the line X-X (Pt. A).
2. Strike a line from Pt. A thru the α_o (15°) to the Y-Y (Pt. B).
3. Strike a line from Pt. B to T (25).
4. Read T^1 = 32 Lbs.

R1 Nomograph (Lbs or Kg)

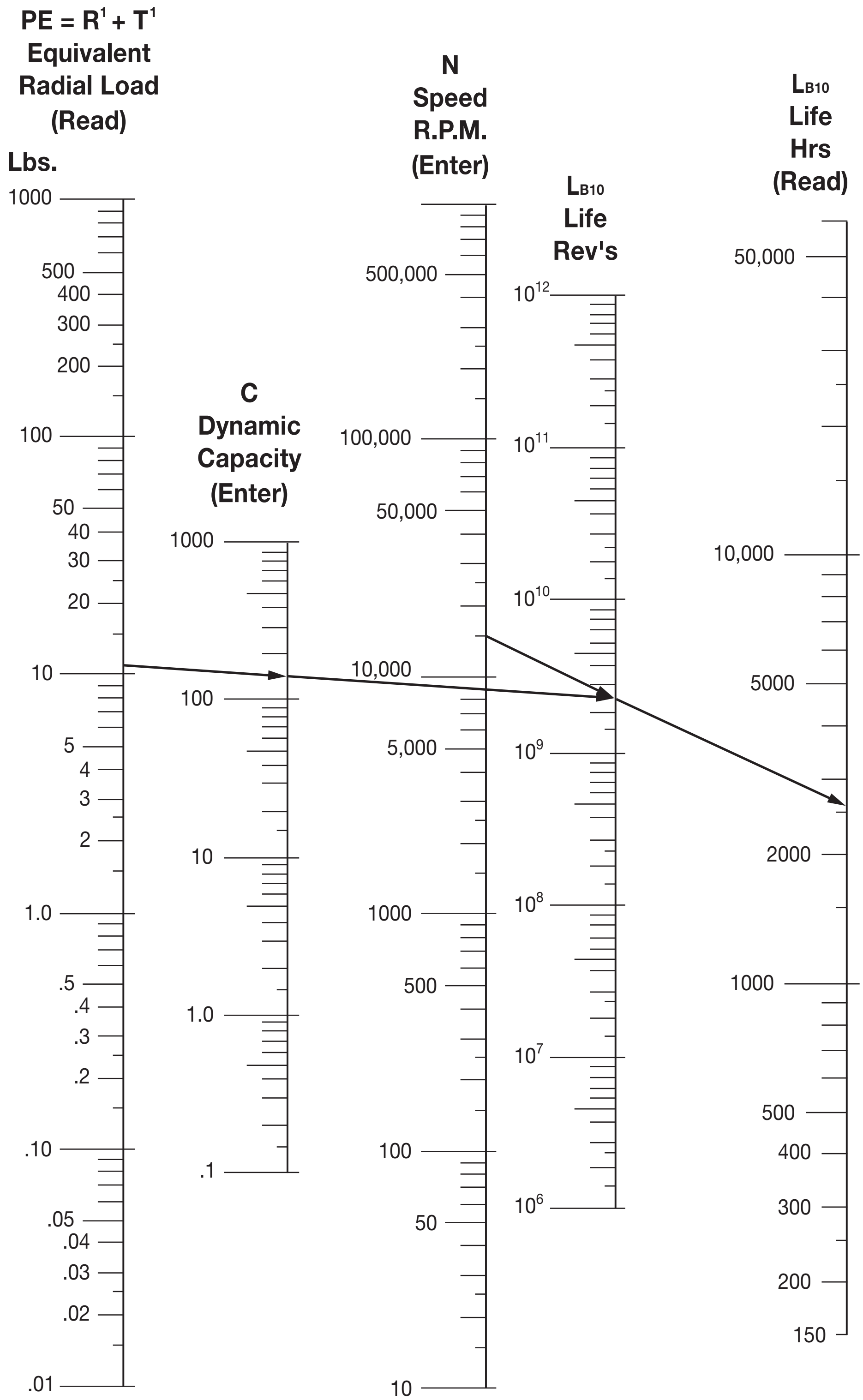


Example: Given Radial Load 2 Lbs.
Contact Angle 9.5°
Read R^1 = .95 Lbs.

To Find R^1:

1. Strike a line from R (2) to $\alpha_\circ$ (9.5°).
2. Read R^1 = .95 Lbs.

B1O Life Nomograph

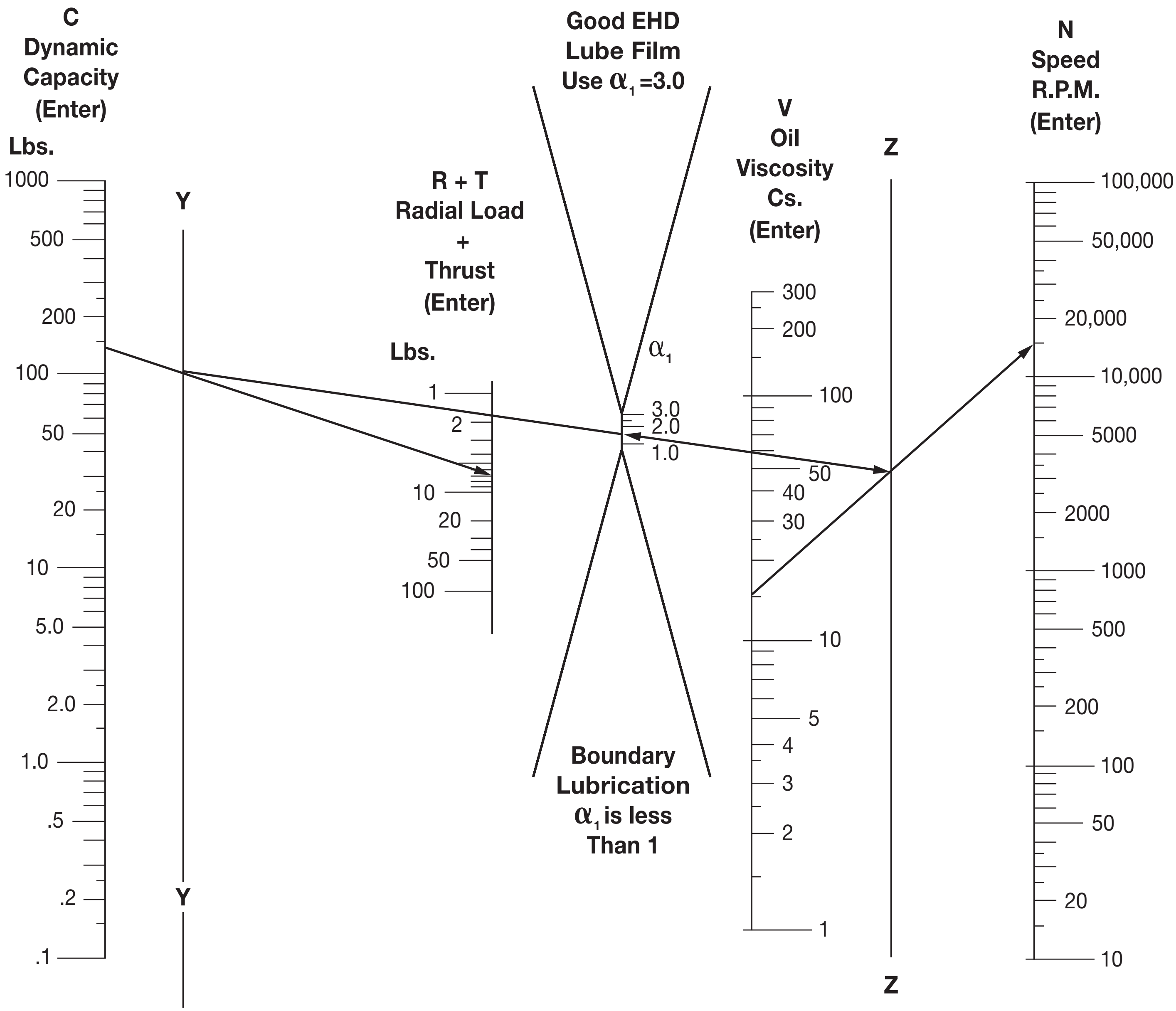


Example: Given PE =10.45 Lbs.
C = 140 Lbs.
Read L_{B10} = 2.4 X 10^9 Revs
Given N = 15,000 R.P.M.
Read L_{B10} = 2700 Hrs.

To Find L_{B10}:

1. Strike a line from PE (10.45) thru C (140) to L_{B10} Life Revolutions.
2. Read L_{B10} Life Revolutions (2.4 X 10^9).
3. Strike a line from Speed – R.P.M. (15,000) thru L_{B10} Life Revolutions (2.4 X 10^9) to L_{B10} Life Hours.
4. Read L_{B10} Life Hours (2700 Hours).

Lubricant Effect Nomograph to Obtain a1 Factor (for Petroleum Oils)



Example: Given C =140 Lbs.
R+T = 7 Lbs.
V = 15 CS
N = 15,000 R.P.M.
Read α_1 = 1.5

To Find α_1:

1. Add R+T (5+2 = 7). Strike line from R+T (7) to C (140).
2. Strike line from R.P.M. (15,000) to Lubricant Viscosity (15).
3. Strike line from intersection of Step 2 with line Z-Z to intersection of Step 1 with Y-Y.
4. Read α_1 = 1.5.

Mounting and Coding

Design of Mating Equipment

A bearing which is fitted too tightly or too loosely, or is damaged during assembly due to excessive force or shock loading, may cause your device to perform in a substandard manner. This possibility can be greatly reduced by following some general guidelines during the design of mating parts (see Table of Recommended Fits on page 53), and by observing the following four cautions during the assembly process.

Caution 1. When establishing shaft or housing sizes, the effect of differential thermal expansion must be accounted for. If thermal gradients are present or dissimilar materials are used, room temperature fits must be adjusted accordingly. Approximate thermal coefficients for common materials are available from NHBB.

Caution 2. When miniature and instrument bearings are interference fitted (either intentionally or as a result of thermal gradients) the bearing radial play is reduced by an amount equal to approximately 80% of the actual diametral interference fit.

Caution 3. If the outer ring or inner ring face is to be clamped or abutted against a shoulder, make sure the shoulder configuration provides a good mounting surface:

- The shoulder face must be perpendicular to the bearing mounting diameter within .0002 inches/per inch.
- The corner between the mounting diameter and the face must have either an undercut or a fillet radius, no larger than that shown on the table pages under the column "r".
- The shoulder diameter must conform to the table on page 53.

Caution 4. It is relatively easy to damage a miniature and instrument bearing during assembly simply by exceeding its load capacity. Adequate fixturing must be provided for handling and assembling precision bearings to ensure that:

- When assembling the bearing to the shaft, force is applied only to the inner ring.
- When assembling into the housing, force is applied only to the outer ring.
- Any movement or shock loads which would be transmitted through the bearing are eliminated.

Coding Classification of Bore and Outside Diameter

When required for selective assembly or for other reasons, bores and/or outside diameters may be classified into coded size groupings within the tolerance ranges specified in this chart. Methods of measuring and determining classification size are specified in ABMA Standard, Section #12.1 and 12.2.

Complete code designation consists of the bore code as the first digit or letter, and the outside diameter code as the second digit or letter. When one dimension only is classified, the other is denoted by 0.

Size Tolerance* (from maximum)	.00005 Calib.	.0001 Calib.
maximum to –.00005	A	1
–.00005 to –.00010	B	
–.00010 to –.00015	C	2
–.00015 to –.00020	D	

*Measurement in inches.

EXAMPLES:

"C12"	Bore Falls Between	0.0000 &	-0.0001
	O.D. Falls Between	-0.0001 &	-0.0002
"CAB"	Bore Falls Between	0.00000 &	-0.00005
	O.D. Falls Between	-0.00005 &	-0.00010
"C10"	Bore Falls Between	0.0000 &	-0.0001
	O.D. Is Not Coded		

Torque

Starting torque and running torque are extremely important in applications such as gyro gimbals, low power consumption motors, and precision positioning devices. In such applications, the total system should be evaluated in the design phase for torque input vs. torque reflected by the various driven components. In many cases, bearing design and manufacture can be modified to reduce torque.

Maximum Starting Torque Values For ABEC 7P Bearings

NHBB Basic Size	Test Load (Thrust) grams	Maximum Starting Torque milligram — millimeters		
		RADIAL PLAY		
		Tight fit .0001" –.0003"	Normal fit .0002" –.0005"	Loose fit .0005" –.0008"
SSRI-2	75	1,800	1,500	1,400
SSRI-2 1/2	75	1,800	1,500	1,400
SSRI-3	75	1,800	1,500	1,400
SSRI-4	75	1,800	1,500	1,400
SSRI-5	75	1,800	1,500	1,400
SSRI-418	75	1,800	1,500	1,400
SSRI-518	75	1,800	1,500	1,400
SSRI-618	75	2,000	1,600	1,500
SSR-2	75	2,000	1,600	1,500
SSRI-618	400	5,000	4,500	4,200
SSR-2	400	5,000	4,500	4,200
SSR-2A	400	5,000	4,500	4,200
SSRI-5532	75	1,800	1,500	1,400
SSRI-5632	75	1,800	1,500	1,400
SSRI-6632	75	2,000	1,600	1,500
SSR-3	400	6,500	5,500	5,000
SSRI-614	75	1,800	1,500	1,400
SSRI-814	400	6,000	5,200	4,800
SSR-4	400	7,000	6,000	5,500
SSRI-1214	400	8,000	7,000	6,500
SSRI-1438	400	11,000	9,500	9,000

Tolerances

Table of Recommended Fits*

Typical Applications	Shaft Fit	Shaft Diameter	Housing Fit	Housing Diameter
Tape guide roller, pulley, cam follower, outer ring rotation	.0000 –.0004L	d –.0002 d –.0004	.0001L –.0003T	D –.0001 D –.0003
Drive motor (spring preload)	.0001T–.0003L	d –.0001 d –.0003	.0000 –.0004L	D +.0002 D –.0000
Precision synchro or servo	.0000 –.0002L**	d –.0001 d –.0003	.0000 –.0002L**	D +.0001 D –.0001
Potentiometer	.0001T–.0003L	d –.0001 d –.0003	.0000 –.0004L	D +.0002 D –.0000
Encoder spindle	.0000 –.0002L**	d –.0001 d –.0003	.0000 –.0002T**	D –.0001 D –.0003

**Measurement in inches.*

L = Loose Fit.
T = Tight Fit.
d = Bearing Bore as listed.

D = Bearing OD as listed.
***Bearings must be purchased with bore and OD coding.*

EXAMPLE: To use SSR-2 bearing in a potentiometer the shaft diameter should be .1250 –.0001 to .1250 –.0003 or .1249 to .1247. The housing should be .3750 +.0002 to .3750 –.0000 or .3752 to .3750.

Table of Recommended Shoulder Diameter*

Basic Size	Minimum Shaft Shoulder Diameter	Maximum Housing Shoulder Diameter
SSRI-2	.060	.105
SSRI-2 1/2	.071	.132
SSRI-3	.079	.164
SSRI-4	.102	.226
SSRI-3332	.114	.168
SSRI-5	.122	.284
SSRI-418	.148	.226
SSRI-518	.153	.284
SSRI-618	.153	.347
SSR-2	.179	.325
SSR-2A	.179	.446
SSRI-5532	.180	.288
SSR-1640X	.210	.580
SSRI-5632	.210	.288
SSRI-6632	.216	.347
SSR-3	.244	.446
SSR-1650X	.250	.580
SSR-1950	.250	.700
SSR-1960	.290	.700
SSRI-614	.272	.352

Basic Size	Minimum Shaft Shoulder Diameter	Maximum Housing Shoulder Diameter
SSRI-814	.284	.466
SSR-4	.310	.565
SSRI-1214	.322	.678
SSR-2270	.325	.810
SSR-2280	.370	.810
SSR-2690	.420	.950
SSRI-8516	.347	.466
SSRI-1038	.435	.565
SSRI-1438	.451	.799
SSRI-2610	.470	.950
SSRI-1212	.560	.690
SSRI-1812	.625	1.025
SSRI-1458	.665	.835
SSRI-1634	.790	.960
SSRI-1218	.160	.710

**Measurement in inches.*

Dimension Control

For more than thirty years, NHBB has been an active member in the American Bearing Manufacturers Association (ABMA) and its associated ball bearing technical committee, the Annular Bearing Engineers' Committee (ABEC).

The ABEC tolerances listed are current at this catalog's printing. These tolerances are reviewed regularly and updated as required. The ABMA Standards may be obtained by contacting: ABMA, 2025 M Street, NW, Suite 800, Washington, DC 20036.

*Tolerances: Miniature and Instrument Ball Bearings Inner Ring**

CHARACTERISTIC	ABEC 1	ABEC 3P	ABEC 5P	ABEC 7P	ABEC 9P
Bore Tolerance Limits	+.0000 –.0003	+.0000 –.0002	+.0000 –.0002	+.0000 –.0002	+.0000 –.0001
Bore 2 pt. out of Roundness	—	—	.0001	.0001	.00005
Bore Taper	—	—	.0001	.0001	.00005
Radial Runout	.0004	.0002 (1)	.00015	.0001	.00005
Width Variation	—	—	.0002	.0001	.00005
Bore Runout with Face	—	—	.0003	.0001	.00005
Race Runout with Face	—	—	.0003	.0001	.00005

**Measurement in inches.*

(1) Add .0001 to the tolerance if bore size is over 10mm (.3937 inch).

Dimension Control

Outer Ring*

CHARACTERISTIC	CONFIGURATION	SIZE RANGE	ABEC 1	ABEC 3P	ABEC 5P	ABEC 7P	ABEC 9P
Mean OD Tolerance Limits	All	0-18mm	+.0000	+.0000	+.0000	+.0000	+.0000
		(0-.7086in)	–.0003	–.0003	–.0002	–.0002	–.0001
	All	over 18-30mm	+.0000	+.0000	+.0000	+.0000	+.0000
		(.7086-1.1181in)	–.0004	–.0003	–.0002	–.0002	–.00015
Maximum OD Tolerance Limits	Open	0-18mm	+.0001	+.0001	+.0000	+.0000	+.0000
		(0-.7086in.)	–.0004	–.0004	–.0002	–.0002	–.0001
		over 18-30mm	+.0001	+.0001	+.0000	+.0000	+.0000
		(.7086-1.1811in)	–.0005	–.0004	–.0002	–.0002	–.00015
	Shielded	0-18mm	+.0002	+.0002	+.00004	+.00004	—
		(0-.7086in)	–.0005	–.0005	–.00024	–.00024	—
		over 18-30mm	+.0002	+.0002	+.00004	+.00004	
		(.7086-1.1811in)	–.0006	–.0005	–.00024	–.00024	
OD 2 pt. out of Roundness	Open	0-18mm	—	—	.0001	.0001	.00005
	Open	over 18-30mm	—	—	.0001	.0001	.00008
	Shielded	0-30mm	—	—	.0002	.0002	—
OD Taper	All	0-18mm	—	—	.0001	.0001	.0005
	All	over 18-30mm	—	—	.0001	.0001	.0008
	Shielded	0-30mm	—	—	.0002	.0002	—
Radial Runout	All	0-18mm	.0006	.0004	.0002	.00015	.00005
	All	over 18-30mm	.0006	.0004	.0002	.00015	.0001
Width Variation	All	0-30mm	—	—	.0002	.0001	.00005
OD Runout with Face	All	0-30mm	—	—	.0003	.00015	.00005
Race Runout with Face	Plain	0-18mm	—	—	.0003	.0002	.00005
	Plain	over 18-30mm	—	—	.0003	.0002	.0001
	Flanged	0-30mm	—	—	.0003	.0003	—
Flange Width Tolerance Limits		—	—	+.0000	+.0000	+.0000	—
		—	—	–.0020	–.0020	–.0020	—
Flange Diameter Tolerance Limits		—	—	+.0050	+.0000	+.0000	—
		—	—	–.0020	–.0010	–.0010	—

**Measurement in inches, unless otherwise indicated.*

Ring Width*

CHARACTERISTIC	CONFIGURATION	ABEC 1	ABEC 3P	ABEC 5P	ABEC 7P	ABEC 9P
Width	Single Bearing	+.000	+.000	+.000	+.000	+.000
		–.005	–.005	–.001	–.001	–.001
	Duplex Pair	—	—	+.000	+.000	+.000
		—	—	–.015	–.015	–.015

**Measurement in inches.*

Post Service Analysis

Our precision miniature and instrument bearings have proven to be highly reliable when used within the defined limits of their capabilities. However, bearings, like any mechanical device, are subject to failure. Failure may occur due to improper mounting, lubrication, environment, loading, maintenance or contamination after installation, as well as workmanship or materials deficiencies.

NHBB maintains a technical staff experienced in the analysis of bearing failure. Using their specialized knowledge, analytical tools and ultra-precision measuring and test equipment, the cause of bearing failure can often be determined. This capability is available to customers experiencing bearing-related problems. In the event that post service bearing analysis is desired, please contact an NHBB Sales Representative, who will make the necessary arrangements.

Hardware and information required to successfully perform a post service analysis include:

- All bearing components and the assembly in which the bearing was used should be made available for examination.
- Bearing manufacturing lot numbers, if available, should be provided.
- Historical information should be provided which describes the conditions under which the device operated, such as speed, loads, temperature and atmospheric conditions to which the bearings were subjected, as well as any unusual shock, vibration, electrical arcing or handling situations to which the device was subjected.

Upon completion of the bearing analysis, a detailed report will be provided noting our findings.

Metric Conversion Table

FRACTION	INCH	mm	FRACTION	INCH	mm	FRACTION	INCH	mm
1/64	0.0156	0.3969	5/16	0.3125	7.9375		0.7087	18.0000
	0.0250	0.6350		0.3150	8.0000	23/32	0.7187	18.2562
1/32	0.0312	0.7937	21/64	0.3281	8.3344	47/64	0.7344	18.6532
	0.0394	1.0000	11/32	0.3437	8.7312		0.7435	18.8849
	0.0400	1.0160		0.3543	9.0000		0.7480	19.0000
3/64	0.0469	1.1906	23/64	0.3594	9.1281	3/4	0.7500	19.0500
	0.0472	1.2000	3/8	0.3750	9.5250	49/64	0.7656	19.4469
	0.0550	1.3970	25/64	0.3906	9.9213		0.7717	19.6012
	0.0591	1.5000		0.3937	10.0000	25/32	0.7812	19.8433
1/16	0.0625	1.5875	13/32	0.4062	10.3187		0.7874	20.0000
	0.0709	1.8000		0.4100	10.4140	51/64	0.7969	20.2402
5/64	0.0781	1.9844	27/64	0.4219	10.7156	13/16	0.8125	20.6375
	0.0787	2.0000		0.4250	10.7950		0.8268	21.0000
	0.0906	2.3012		0.4331	11.0000	53/64	0.8281	21.0344
3/32	0.0937	2.3812	7/16	0.4375	11.1125	27/32	0.8437	21.4312
	0.0984	2.5000	29/64	0.4531	11.5094	55/64	0.8594	21.8281
	0.1000	2.5400		0.4600	11.6840		0.8661	22.0000
	0.0124	2.6000	15/32	0.4687	11.9062	7/8	0.8750	22.2250
7/64	0.1094	2.7781		0.4724	12.0000	57/64	0.8906	22.6219
	0.1100	2.7940	31/64	0.4844	12.3031		0.9055	23.0000
	0.1102	2.8000	1/2	0.5000	12.7000	29/32	0.9062	23.0187
	0.1181	3.0000		0.5118	13.0000	59/64	0.9219	23.4156
1/8	0.1250	3.1750	33/64	0.5156	13.0968	15/16	0.9375	23.8125
	0.1256	3.1902	17/32	0.5312	13.4937		0.9449	24.0000
	0.1378	3.5000	35/64	0.5469	13.8906	61/64	0.9531	24.2094
9/64	0.1406	3.5719		0.5512	14.0000	31/32	0.9687	24.6062
5/32	0.1562	3.9687	9/16	0.5625	14.2875		0.9843	25.0000
	0.1575	4.0000	37/64	0.5781	14.6844	63/64	0.9844	25.0031
11/64	0.1719	4.3656		0.5906	15.0000		1.0000	25.4000
3/16	0.1875	4.7625	19/32	0.5937	15.0812		1.0236	26.0000
	0.1892	4.8057	39/64	0.6094	15.4781		1.0415	26.4541
	0.1969	5.0000	5/8	0.6250	15.8750		1.0480	26.6192
13/64	0.2031	5.1594		0.6299	16.0000	1-1/16	1.0625	26.9875
	0.2165	5.4991	41/64	0.6406	16.2719		1.0630	27.0000
7/32	0.2187	5.5562		0.6500	16.5100		1.1025	28.0000
15/64	0.2344	5.9531	21/32	0.6562	16.6687	1-1/8	1.1250	28.5750
	0.2362	6.0000		0.6620	16.8148		1.1417	29.0000
1/4	0.2500	6.3500		0.6693	17.0000		1.1812	30.0000
17/64	0.2656	6.7469	43/64	0.6719	17.0656	1-3/16	1.1875	30.1625
	0.2756	7.0000	11/16	0.6875	17.4625	1-1/4	1.2500	31.7500
9/32	0.2812	7.1437	45/64	0.7031	17.8594	1-1/2	1.5000	38.1000
	0.2883	7.3228						
19/64	0.2969	7.5406						

Interchange Chart

NHBB	NMB	MPB	BARDEN	RMB	NEW HAMPSHIRE
SSRI-2	DDRI-2	S2C	SR0-9	UL1304X	SR09
SSRI-2 1/2	DDRI-2 1/2	S2 1/2C	SR0	UL1505X	SR0
SSRI-2 1/2ZZ	DDRI-2 1/2ZZ	S2 1/2CHH	SR0SS	ULZ1505X	SR0PP
SSRI-3	DDRI-3	S3C	SR1	R1706X	SR1
SSRI-3ZZ	DDRI-3ZZ	S3CHH	SR1SS	RF1706X	SR1PP
SSRI-4	DDRI-4	S4C	SR1-4	R2508X	SR1-4
SSRI-4ZZ	DDRI-4ZZ	S4CHH	SR1-4SS	RF2508X	SR1-4PP
SSRI-3332	DDRI-3332	S3332C	SR133	UL3006X	SR133
SSRI-3332ZZ	DDRI-3332ZZ	S3332CHH	SR133SS	ULZ3006X	SR133PP
SSRI-5	DDRI-5	S5C	SR1-5	R3010X	SR1-5
SSRI-5ZZ	DDRI-5ZZ	S5CHH	SR1-5SS	RF3010X	SSR1-5PP
SSRI-418	DDRI-418	S418C	SR144	UL4008X	SR144
SSRI-418ZZ	DDRI-418ZZ	S418CHH	SR144SS	ULZ4008X	SR144PP
SSRI-518	DDRI-518	S518C	SR2-5	R4010X	SR2-5
SSRI-518ZZ	DDRI-518ZZ	S518CHH	SR2-5SS	RF4010X	SR2-5PP
SSRI-618	DDRI-618	S618C	SR2-6		SR2-6
SSRI-618ZZ	DDRI-618ZZ	S618CHH	SR2-6SS		SR2-6PP
SSR-2	DDR-2	SR2C	SR2	R4012X	SR2
SSR-2ZZ	DDR-2ZZ	SR2CHH	SR2SS	RF4012X	SR2PP
SSR-2A	DDR-2A	SR2AC	SR2A		SR2A
SSR-2ZZA	DDR-2ZZA	SR2ACHH			SR2APP
SSRI-5532	DDRI-5532	S5532C	SR155	UL5010X	SR155
SSRI-5532ZZ	DDRI-5532ZZ	S5532CHH	SR155SS	UL5010Z	SR155PP
SSRI-5632	DDRI-5632	S5632C	SR156	UL6010X	SR156
SSRI-5632ZZ	DDRI-5632ZZ	S5632CHH	SR156SS	ULZ6010X	SR156PP
SSRI-6632	DDRI-6632	S6316C	SR166	UL6012X	SR166
SSRI-6632ZZ	DDRI-6632ZZ	S6316CHH	SR166SS	ULZ6012X	SR166PP
SSR-3	DDR-3	SR3R	SR3	R6016X	SR3
SSR-3ZZ	DDR-3ZZ	SR3RHH	SR3SS	RF6016X	SR3PP
SSRI-614	DDRI-614	S614C	SR168	UL8012X	SR168
SSRI-614ZZ	DDRI-614ZZ	S614CHH	SR168SS	ULZ8012X	SR168PP
SSRI-814	DDRI-814	S814C	SR188	UL8016X	SR188
SSRI-814ZZ	DDRI-814ZZ	S814CHH	SR188SS	ULZ8016X	SR188PP
SSR-4	DDR-4	SR4C	SR4	R8020X	SR4
SSR-4ZZ	DDR-4ZZ	SR4CHH	SR4SS	RF8020X	SR4PP
SSRI-1214	DDRI-1214	SR4AR		SR4A	SR4AD
SSRI-1214ZZ	DDRI-1214ZZ	SR4ARHH	SR4ASS		SR4APPD
SSRI-8516	DDRI-8516	S8516R	SR1810		SR1810
SSRI-8516ZZ	DDRI-8516ZZ	S8516RHH	SR1810SS		SR1810PP
SSRI-1438	DDRI-1438	SR6R	SR6		SR6D

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NHBB	NMB	MPB	BARDEN	RMB	NEW HAMPSHIRE
SSRI-1438ZZ	DDRI-1438ZZ	SR6RHH	SR6SS		SR6PPD
SSRI-1812	DDRI-1812	SR8R	SR8		SR8D
SSRI-1812ZZ	DDRI-1812ZZ	SR8RHH	SR8SS		SR8PPD
SSRIF-2	DDRIF-2	S2FC	SFR09	ULK1304X	SFR09
SSRIF-2 1/2	DDRIF-2 1/2	S2 1/2FC	SFR0	ULK1505X	SFR0
SSRIF-2 1/2ZZ	DDRIF-2 1/2ZZ	S2 1/2FCHH	SFR0SS	ULKZ1505X	SFR0PP
SSRIF-3	DDRIF-3	S3FC	SFR1	RK1706X	SFR1
SSRIF-3ZZ	DDRIF-3ZZ	S3FCHH	SFR1SS	RKF1706X	SFR1PP
SSRIF-4	DDRIF-4	S4FC	SFR1-4	RK2508X	SFR1-4
SSRIF-4ZZ	DDRIF-4ZZ	S4FCHH	SFR1-4SS	RKF2508X	SFR1-4PP
SSRIF-3332	DDRIF-3332	S3332FC	SFR133	ULK3006X	SFR133
SSRIF-3332ZZ	DDRIF-3332ZZ	S3332FCHH	SFR133SS	ULKZ3006X	SFR133PP
SSRIF-5	DDRIF-5	S5FC	SFR1-5	RK3010X	SFR1-5
SSRIF-5ZZ	DDRIF-5ZZ	S5FCHH	SFR1-5SS	RKF3010X	SFR1-5PP
SSRIF-418	DDRIF-418	S418FC	SFR144	ULK4008X	SFR144
SSRIF-418ZZ	DDRIF-418ZZ	S418FCHH	SFR144SS	ULKZ4008X	SFR144PP
SSRIF-518	DDRIF-518	S518FC	SFR2-5	RK4010X	SFR2-5
SSRIF-518ZZ	DDRIF-518ZZ	S518FCHH	SFR2-5SS	RKF4010X	SFR2-5PP
SSRIF-618	DDRIF-618	S618FC	SFR2-6		SFR2-6
SSRIF-618ZZ	DDRIF-618ZZ	S618FCHH	SFR2-6SS		SFR2-6PP
SSRF-2	DDRF-2	SR2FC	SFR2	RK4012X	SFR2
SSRF-2ZZ	DDRF-2ZZ	SR2FCHH	SFR2SS	RKF4012X	SFR2PP
SSRIF-5532	DDRIF-5532	S5532FC	SFR155	ULK5010X	SFR155
SSRIF-5532ZZ	DDRIF-5532ZZ	S5532FCHH	SFR155SS	ULKZ5010X	SFR155PP
SSRIF-5632	DDRIF-5632	S5632FC	SFR156	ULK6010X	SFR156
SSRIF-5632ZZ	DDRIF-5632ZZ	S5632CHH	SFR156SS	ULKZ6010X	SFR156PP
SSRIF-6632	DDRIF-6632	S6316FC	SFR166	ULK6012X	SFR166
SSRIF-6632ZZ	DDRIF-6632ZZ	S6316FCHH	SFR166SS	ULKZ6012X	SFR166PP
SSRF-3	DDRF-3	SR3FC	SFR3X3		SFR3C
SSRF-3ZZ	DDRF-3ZZ	SR3FCHH	SFR3SS	RKF6016X	SFR3PP
SSRIF-614	DDRIF-614	S614FC	SFR168	ULK8012X	SFR168
SSRIF-614ZZ	DDRIF-614ZZ	S614FCHH	SFR168SS	ULKZ8012X	SFR168PP
SSRIF-814	DDRIF-814	S814FC	SFR188	ULK8016X	SFR188
SSRIF-814ZZ	DDRIF-814ZZ	S814FCHH	SFR188SS	ULKZ8016X	SFR188PP
SSRF-4	DDRF-4	SR4FC	SFR4	RK8020X	SFR4
SSRF-4ZZ	DDRF-4ZZ	SR4FCHH	SFR4SS	RKF8020X	SFR4PP
SSRIF-8516	DDRIF-8516	S8516FC	SFR1810		SFR1810
SSRIF-8516ZZ	DDRIF-8516ZZ	S8516FCHH	SFR1810SS		SFR1810PP
SSRIF-1438	DDRIF-1438		SFR6X5		SFR6DC
SSRIF-1438ZZ	DDRIF-1438ZZ	SR6FRHH	SFR6SS		SFR6PPD

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