Bearings and Power Transmission RESOURCE GUIDE

Part 3: Bearings

Reid Supply Company®

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Bearings and Power Transmission
Part 3: Bearings

- Ball Bearings
- Bronze Sleeve Bearings
- Cam Followers
- Cylindrical Roller Bearings
- Deep Groove Ball Bearings
- Graphic-Metal Bearings
- Metric Dry Bearings
- Mounted Bearings

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Reid Supply Resource Guides

In our continuous effort to improve our offerings and meet Customer needs, simplify effort and provide solutions, Reid Supply has separated our products into 12 easy-to-identify categories:

Manual Controls	-	Blue
Clamps and Workholding	-	Red
Tooling Components	-	Gold
Fasteners and Hardware	-	Blue Green
Leveling Devices and Vibration Control	-	Orange
Material Handling	-	Purple
Bearings and Power Transmission	-	Blue Gray
Metalworking	-	Brown
Maintenance, Repair and Operations	-	Aqua
Pneumatics and Hydraulics	-	Dark Red
Structural Systems	-	Yellow Green
Safety	-	Orange Yellow

Bearings and Power Transmission is the sixth of a series of Resource Guides relative to each of 12 categories. Each Resource Guide includes detailed application information, data and references to help our customers select the best product for their intended application. To better manage content within the Bearings and Power Transmission Resource Guide, it has been divided into four parts:

Part 1: Motors

Part 2: Mechanical Drive Systems

Part 3: Bearings

Part 4: Machine Components

Reid Supply welcomes your feedback and comments on any aspect of these Resource Guides. Please contact Customer Service at the number listed below or email us at **mail@ReidSupply.com**.

PURPOSE OF THIS RESOURCE GUIDE

Discussing all aspects of bearings, their design, and application is beyond the scope of this guide. As part three of a four-part series for the Bearings and Power Transmission Resource Guides, this guide provides information to help with the selection and replacement of bearings and bearing components. It is not intended to be a how-to manual, however, much of the information presented is relative to the selection and proper use of bearings. The Resource Guide extends beyond the Reid Supply catalog to provide details, tables, charts, regulations and standards, reference material and more to further assist engineers, designers, maintenance personnel, users and others in selecting and applying the best parts for Bearings and Power Transmission needs relative to bearings. If more information is required for design and application purposes, the reference manuals listed in Table 41 and Table 42 can provide this information.

DISCLAIMER

It should be noted that ***this Resource Guide is for reference only***. The information provided is intended to assist in the selection of products sold by Reid Supply and its vendors. As Reid Supply and its vendors are not typically aware of or possess any expertise in the systems or processes for which products are to be applied, we cannot accept any responsibility or liability for the outcome thereof.

Furthermore, with new and old technologies continually expanding and changing, it is impossible to address all systems, processes and applications for which Reid Supply products are purchased. Reid Supply also has little control over materials and processes from which our products are produced.

In addition, due to the nature of some materials; colors, textures, shapes and sizes may lack consistency.

Products sold by Reid Supply are sold with the understanding that the purchaser is thoroughly familiar with the safe and proper use and application of the product. Responsibility for the use and application of the products rests with the user. Failure of the product can occur due to misapplication, abuse, intentional alteration or improper maintenance.

WARNING: Improper application, use, or operation of Bearings and Power Transmission systems and components can cause damage to equipment, destruction of transported material, personal injury or death. Where applicable, statements are included in this document to stress the importance of safety as it applies to the design, application, use and/or operation of Bearings and Power Transmission systems and components.

Specifications for Bearings and Power Transmission products apply at the time of purchase only. Application and use, proper or improper, can change the characteristics of the Bearings and Power Transmission system and its components. The user is solely responsible for any recommended or mandatory maintenance and inspection of these products, documented or undocumented, by the vendor, professional organization, or governmental body relative to the Bearings and Power Transmission system or component purchased. Furthermore, the user shall be solely responsible for the safe application, operation and use of all products purchased at Reid Supply.

Reid Supply reserves the right to modify, update and otherwise maintain this document and its content.

HOW TO USE THIS GUIDE

The tables, charts, figures and other information included in this manual are useful tools for the selection, application and use of motors. This technical information helps the reader quickly compare specifications and data between similar motors and their attributes. Starting with the Table of Contents, locate the desired information. As a PDF file, bookmarks are also included that can be accessed within Acrobat Reader for navigation. The search feature of Acrobat Reader is another useful navigation tool.

Useful tools include:

- Professional regulations and standards, along with government safety regulations, improve application design and performance, not to mention compliance requirements. See Table 1.
- Product pros and cons allow customers to compare products relative to application specifications.
- Links send the reader directly to related information within this document, on the Internet, or to pre-defined online catalog searches relative to the products listed.
- Reference material that goes beyond the Resource Guide to engineering level formulas, details and discussion. Refer to Table 41 and Table 42.

NOTE: References used are listed at the end of this manual and referred to by number, e.g. [3], in the text. References to text books and other documentation sold by Reid Supply are also referred to by number, e.g. {5}, as listed in Table 15 at the end of this manual.

Terminology

Some terms used to define products may be vendor and product specific. To avoid confusion, a glossary of terms used in this document has been included at the end of the manual.

As Reid Supply purchases its products from several vendors, it is sometimes challenging to sort and categorize these differences. If you find yourself confused by terminology in the catalog or this document, try shopping online using the web site listed below, contact Customer Service at the number listed below, or email us at **mail@**ReidSupply**.com**.

Safety

Mechanical systems and components are potentially hazardous. Common sense, knowledge, experience, and safe operating practices should be exercised during operation, service and mechanical systems and moving parts. Service and repair of mechanical system should only be performed by authorized, certified professionals.

Safety standards are available from the Occupational Safety and Health Association (OSHA). If in doubt and safety guidelines are not included with your purchase, contact Reid Customer Service and the proper documentation or other information will be provided. Safety seminars are also available for some products.

DESIGN CONSIDERATIONS

Design considerations for bearings are established by government regulations and professional standards organizations; such as those listed in Table 1. These standards govern bearing design, identification and application to ensure world wide compatibility. The application of bearings includes most any situation where the effects of friction and loads between two moving components must be reduced and controlled. Some of the information found in these standards are included in this guide give the reader a better understanding of their content and how it is applied. This information is useful in the selection of bearings for application and replacement purposes.

Engineering design considerations are included in much of the reference material listed in Table 41 and by contacting Customer Service.

REGULATIONS

There are many governmental, professional, and organizational standards and regulations for best practices and safety issues relative to Bearings and Power Transmission systems. A majority of the included information relates to the design, application, and operation of bearings, bearing components and systems. Some are also related to testing methods. Table 1 includes a sample of regulation and standards organizations. Along with Table 2, Table 1 also includes some standards, by number, relative to bearings and Mil-Specs.

Selecting components designed, manufactured, and applied according to these standards has the advantage of:

- Improving the chance replacement parts will be available for the life of the machine, system, or process.
- Quality standards will be applied for repeatability, tolerances, and fit.
- Years of experience, knowledge and testing has been shared for improved design and manufacture of components and systems.
- Publicly available documentation and reference material.

This Resource Guide includes data tables and other information found in many of these regulations relative to selection and maintenance of bearings. More detailed content can be obtained online at the respective sites listed in Table 1 or in many of the references listed in Table 41.

NOTE: Many regulations and standards are “recommended”. Adhering to and applying the content of these regulations and standards in mostly voluntary for manufactures, designers and operators of bearings and bearing components. In most cases, manufactures and designers will meet or exceed the documented specifications.

Regulations and standards are periodically revised, superseded or otherwise managed to keep up with changes in technology, materials, design, manufacturing, and testing methods.

Table 1: *Standards for Bearings and Power Transmission Systems and Components*

Standard[1]	Number[1]	Mil-Spec	Function
ABMA American Bearing Manufacturer's Association www.abma-dc.org	ABMA is a non-profit association consisting of American manufacturers of anti-friction bearings, spherical plain bearings or major components thereof. The purpose of ABMA is to define national and international standards for bearing products and maintain bearing industry statistics. The ABMA has become the collective voice of the American bearing industry, influencing government policies and international trade. ABMA member companies manufacture 85 percent of the bearings produced in the United States. The American Bearing Manufacturers Association was formerly known as the Anti-Friction Bearing Manufacturers Association. Refer to Table 2 for a list of shared standards.		
	8.2		Ball and Roller Bearing – Mounting Accessories – Inch Design
ANSI American National Standards Institute www.ansi.org	ANSI facilitates the development of American National Standards (ANS) by accrediting the procedures of standards developing organizations (SDOs). These groups work cooperatively to develop voluntary national consensus standards. Refer to Table 2 for a list of shared standards.		

Standard[1]	Number[1]	Mil-Spec	Function
ASTM International www.astm.org	Formerly the American Society for Testing and Materials, ASTM International is one of the largest voluntary standards development organizations in the world–a trusted source for technical standards for materials, products, systems, and services. Known for their high technical quality and market relevancy, ASTM International standards have an important role in the information infrastructure that guides design, manufacturing and trade in the global economy.		
	A534	X	Steels, Carburizing For Anti-friction Bearings
	B438/B438M	X	Standard Specification For Bronze-base Powder Metallurgy (Pm) Bearings (Oil-impregnated)
	B439	X	Standard Specification For Iron-base Powder Metallurgy (Pm) Bearings (Oil-impregnated)
	D217		Standard Test Methods For Cone Penetration Of Lubricating Grease
	D1403		Standard Test Methods For Cone Penetration Of Lubricating Grease Using One-quarter And One-half Scale Cone Equipment
	D2422		Standard Classification Of Industrial Fluid Lubricants By Viscosity System
	D3336	X	Life Of Greases, Lubricating, In Ball Bearings At Elevated Temperatures
	D3337	X	Determining Life And Torque Of Greases, Lubricating, In Small Ball Bearings
	F2215	X	Standard Specification For Balls, Bearings, Ferrous And Nonferrous For Use In Bearings, Valves, And Bearing Applications
	F2332		Standard Specification For Annular Ball Bearings For Instruments And Precision Rotating Components
	F2488		Standard Terminology For Rolling Element Bearings
CSA Canadian Standards Association www.CSA.ca	The Canadian Standards Association is a not-for-profit membership-based association serving business, industry, government and consumers in Canada and the global marketplace.		
DIN Deutsches Institut for Normung e.V. www.normas.com/DIN	Over 10,000 standards published by DIN, the self-governing institution of trade and industry which is responsible for the preparation of National Standards in Germany.		
	21.100		Mechanical Systems And Components For General Use: Bearings

Standard[1]	Number[1]	Mil-Spec	Function
ISO International Organization for Standardization www.iso.org	ISO is the world's largest developer and publisher of International Standards. It is a non-governmental organization network of the national standards institutes of 157 countries, one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system. Refer to Table 2 for a list of shared standards.		
	15		Rolling Bearings – Radial Bearings – Boundary Dimensions, General Plan
	76		Rolling Bearings – Static Load Ratings
	113		Rolling Bearings – Plummer Block Housings – Boundary Dimensions
	199		Rolling Bearings – Thrust Bearings – Tolerances
	204		Rolling Bearings – Thrust Bearings – Boundary Dimensions, General Plan
	246		Boundary Dimensions – Cylindrical Roller Bearings, Separate Thrust Collars
	281		Calculating The Dynamic Operating Lifespan And Load Ratings For Rolling Element Bearings
	355		Rolling Bearings – Tapered Roller Bearings – Boundary Dimensions And Series Designations
	1224		Rolling Bearings – Instrument Precision Bearings
	1132-1		Rolling Bearings – Tolerances – Part 1: Terms And Definitions
	1132-2		Rolling Bearings – Tolerances – Part 2: Measuring And Gauging Principles And Methods
	1206		Irolling Bearings – Needle Roller Bearings, Dimension Series 48, 49 And 69 – Boundary Dimensions And Tolerances
	2795		Dimensions And Tolerances For Plain Bearings And Sintered Bushes
	3104		Petroleum Products – Transparent And Opaque Liquids -- Determination Of Kinematic Viscosity And Calculation Of Dynamic Viscosity
	3290	X	Rolling Bearings – Balls – Dimensions And Tolerances
	3448		Industrial Liquid Lubricants -- Iso Viscosity Classification
	10285		Rolling Bearings, Linear Motion, Recirculating Ball, Sleeve Type – Metric Series
	10317		Rolling Bearings – Metric Tapered Roller Bearings – Designation System
	11687-1		Plain Bearings – Pedestal Plain Bearings – Part 1: Pillow Blocks
	11687-2		Plain Bearings – Pedestal Plain Bearings – Part 2: Side Flange Bearings
	11687-3		Plain Bearings – Pedestal Plain Bearings – Part 3: Center Flange Bearings
	12129-1		Plain Bearings – Part 1: Fits
	12129-2		Plain Bearings – Part 2: Tolerances On Form And Position And Surface Roughness For Shafts, Flanges And Thrust Collars
	15241		Rolling Bearings – Symbols For Quantities
JIS Japanese Industrial Standards Committee www.jisc.go.jp/eng	Japanese equivalent to ANSI.		
	B 1512		Rolling Bearings – Boundary Dimensions
	B 1514		Rolling Bearings – Tolerances

Standard[1]	Number[1]	Mil-Spec	Function
MIL-STD US Military Standard Maintained by DSCC. www.dscc.dla.mil	DSCC serves as a preparing activity or technical agent for thousands of standardization documents covering a wide variety of electronic components and other items. Our engineers and technicians coordinate and prepare technical documents in 67 Federal Supply Classes, and provide engineering support to DoD customers using these documents.		
	MIL-B-913 SUP 1		General Specification For Bearings, Ball, Annular, For Instruments And Precision Rotating Components (Metric). Scope: This specification covers annular ball bearings intended primarily for use in instruments and precision rotating components.
	MIL-L-15719A(3)		Lubricating Grease (High-temperature, Electric Motor, Ball And Roller Bearings)
	MIL-N-21337		Nut, Plain, Round, Retaining, Ball And Roller Bearings
	MIL-B-81793D(1) SUP 1		Bearings, Ball, Annular, For Instruments And Precision Rotating Components Scope: This specification covers annular ball bearings intended primarily for use in instruments and precision rotating components.
	MIL-STD-1647E		Identification Markings For Domestically Manufactured Bearings, Ball, Annular For Instruments And Precision Components
	MIL-HDBK-203C		Manufacturers Symbols And Designations For Anti-friction Bearings Scope: This handbook is intended as a guide for the interpretation of anti-friction bearing manufacturers symbols and designation. It is intended for personnel concerned with the preparation of specifications, procurement of bearings and identification of bearings.
	MIL-HDBK-1599A(1) NOT 2		Bearings, Control System Components, And Associated Hardware Used In The Design And Construction Of Aerospace Mechanical Systems And Subsystems Scope: This handbook is intended to assist engineers in the design and construction of aerospace mechanical systems for military aircraft. It is intended to serve the engineer by fostering the use of approved standards parts while allowing the freedom to choose non-standard or special parts when a particular application warrants it. It is intended to neither tie the designer's hands nor to grant unlimited license. This handbook is intended to assist engineers: (a) by providing design guidance based on industry-proven engineering practices for bearings, control system components and associated hardware used in aerospace mechanical systems; (b) by requiring the use of approved standard parts in these systems to the largest extent practicable; and (c) by providing for the selection and approval of special parts, when those are necessary and appropriate, through the use of defined procedures.
NLGI National Lubricating Grease Institute www.NLGI.org	NLGI was incorporated in 1933 as the National Association of Lubricating Grease Manufacturers, Inc., for the purpose of writing a code concerning the NRA (National Recovery Act). In 1937, the name was changed to the National Lubricating Grease Institute. Its founders were J.R. Battenfeld, Battenfeld Grease & Oil Corporation; Guy Peters, Oil Craft Inc.; and W.H. Sauders, International Lubricant Corp. Another name change was made to NLGI in 2001. Today, NLGI continues to promote the technical advancement of grease lubrication, and contributes materially to greater production, increased machine life and a higher quality of machine performance through better lubrication.		

Standard[1]	Number[1]	Mil-Spec	Function
SAE International Society of Automotive Engineers www.sae.org	SAE International has more than 90,000 members – engineers, business executives, educators, and students from more than 97 countries; who share information and exchange ideas for advancing the engineering of mobility systems. SAE is your one-stop resource for standards development, events, and technical information and expertise used in designing, building, maintaining, and operating self-propelled vehicles for use on land or sea, in air or space.		
	AMS4800	X	Bearings, Babbitt 91sn – 4.5sb – 4.5cu
	AMS4805	X	Bearings, Sintered Metal Powder 89cu – 10sn Oil Impregnated
	AMS4816	X	Bearings, Silver-clad Steel Strip
	AMS4820	X	Bearings, Leaded Copper 70cu – 28.5pb Steel Back
	AMS4827	X	Bearings, Leaded Bronze 80cu – 10pb – 10sn Steel Back
	AS6038	X	Bearings, Ball, Bellcrank, Anti-friction, Airframe
	AS6039	X	Bearings, Ball, Rod End, Double-row, Self-aligning
	AS7949	X	Bearings, Ball, Airframe, Anti-friction
	AS8952	X	Bearings, Roller, Rod End, Anti-friction Self-aligning
	AS8976	X	Bearings, Plain, Self-aligning, All Metal
	AS13341	X	Process For Barrier Coating Of Anti-friction Bearings
	AS17108	X	Bearings, Ball, Annular, Primarily For Aircraft Generators, Type II
	AS39901	X	Bearings, Roller, Needle, Airframe, Anti-friction, Inch
	AS81820	X	Bearings, Plain, Self-aligning, Self-lubricating, Low Speed Oscillation
	AS81934	X	Bearings, Sleeve, Plain And Flanged, Self-lubricating
	AS81935	X	Bearings, Plain, Rod End, Self-aligning, Self-lubricating
	AS81935/1	X	Bearings, Plain, Rod End, Self-aligning, Self-lubricating, Wide, Externally Threaded, -65 To +325 Deg F
	AS81935/3	X	Locking Devices (For Rod End Bearings)
	AS81936	X	Bearings, Plain, Self-aligning (Cu-be Ball, Cres Race)
	J506	X	Sleeve Type Half Bearings

NOTES: [1] Reid Supply does not design, fabricate or manufacture any of its products. The professional, safety and standard organizations, plus related documentation, listed are for reference only and may not be complete or up-to-date. The vendor, customer, purchaser and user is responsible for obtaining, understanding and applying any regulations and standards, safety or otherwise, relative to the application and use of all Reid Supply products.

Table 2: *Common Standards Cross Reference*

Standards Title	Agencies			
	ABMA	ANSI	ISO	Mil-Spec
Tolerance Definitions and Gaging Practices for Ball and Roller Bearings	4			
Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plan	7			X
Ball and Roller Bearing Mounting Accessories – Metric Design	8.1			
Load Ratings and Fatigue Life for Ball Bearings	9			
Rolling bearings – Balls – Dimensions and Tolerances	10			
Load Ratings and Fatigue Life for Roller Bearings	11			
Instrument Ball Bearings – Inch and Metric Design	12			X
Rolling Bearing Vibration and Noise (Methods of Measuring)	13			
Housings for Bearings with Spherical Outside Surfaces	14			

Standards Title	Agencies			
	ABMA	ANSI	ISO	Mil-Spec
Ball Bearings With Spherical Outside Surfaces And Extended Inner Ring Width (Includes Eccentric Locking Collars)	15			
Needle Roller Bearings Radial – Inch And Metric Design	18			X
Tapered Roller Bearings – Radial – Inch And Metric Design	19			X
Radial Bearings Of Ball, Cylindrical Roller And Spherical Roller Types – Metric Design	20			X
Thrust Needle Roller And Cage Assemblies And Thrust Washers – Inch And Metric Design	21			
Spherical Plain Radial Bearings, Joint Type – Inch And Metric Design	22			X
Thrust Bearings Of Tapered Roller Type – Inch And Metric Design	23			X
Thrust Bearings Of Ball, Cylindrical Roller And Spherical Roller Types – Inch And Metric Design	24			X
Rolling Bearings, Linear Motion Recirculating Ball, Sleeve Type – Inch And Metric Design	25			X
Thin Section Ball Bearings – Inch And Metric Design	26			X
Rolling Bearings – Thrust Bearings – Boundary Dimensions, General Plan	104			
Rolling Bearings – Thrust Bearings – General Plan	199			
Rolling Bearings, Needle Rollers, Dimensions And Tolerances	3096			
Rolling Bearings – Vocabulary	5593			
Rolling Bearings, Linear Motion, Recirculating Ball, Sleeve Type-metric Series	10285			
Spherical Plain Bearings (Parts 1, 2, 3, & 4)	12240			X
Aerospace Bearing Standards	13411–13417 14190–14221			

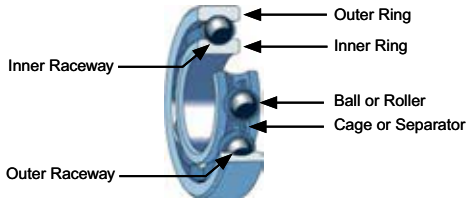
NOTE: Many industrial and military standards can be found at www.nssn.org (powered by ANSI).

BEARING BASICS

In early Egypt, logs were used as rollers to move large blocks to built the pyramids. Since that time, bearings have been used in many ways to ease the effects of gravity and friction in many applications.

According to the ABMA – Bearings are highly engineered, precision-made components...enabling machinery to move at extremely high speeds and carry remarkable loads with ease and efficiency. Bearings must be able to offer high precision, reliability and durability, as well as the ability to rotate at high speeds with minimal noise and vibration. Bearings are found in applications ranging from automobiles, trains and airplanes, computers, construction equipment, machine tools, VCRs, refrigerators and ceiling fans.

Figure 1: *Basic Components of a Plain Bearing*



At first glance, bearings seem simple (Figure 1): a set of balls, rollers or pins, sandwiched between an inner and outer ring; lubrication required. But, in considering the forces impacting each bearing employed in an extremely diverse set of applications, it is easy to see that one, or even a few, bearing designs are not enough to satisfy all, or most, design considerations and performance demands. Some of the factors that can work against expected bearing performance include:

Applied forces Depending on the application, how, and where the bearing is mounted, one or more applied forces work against inner and outer bearing surfaces. This will be discussed in more detail in the section on Bearing Loads.

Fit In order for a plain bearing (Figure 1) to properly function, one ring must be stationary while the other is free to rotate. There are several ways to make a bearing component stationary and most involve clamping of some type and/or a pressure fit. A loosely mounted bearing generates slip and results in unintended bearing surfaces that work to destroy the bearing and all contact surfaces. Loose components can produce noise, vibration and shock loads relative to speed.

Lubrication Friction is always associated with wear, heat and limited life of all components involved. Proper and regular lubrication greatly reduces wear and heat while maximizing the life of mechanical parts. Improper, or lack of, lubrication can destroy a bearing and all related contact surfaces; and these adverse effects increase with speed.

Noise Any movement produces noise at some level, especially when metal moves against metal. Noise is minimized by precision design and proper lubrication. Noise can also be an indication of a failing bearing.

Speed Friction, noise, and vibration are multiplied by speed, especially for non-precision bearings with light loads. The need for lubrication increases with speed.

Vibration Depending on the source of the vibration (out of balance or loose components), the quantity, direction, and impact of the applied forces can change. Vibration also results in shock loads against bearing components.

Types of Bearings

A plain bearing is one that provides a sliding contact between mating surfaces. These types of bearings are grouped into four general groups:

Table 3: *Basic Bearing Types*

Primary Bearing Types	Secondary Type	Description
Guide	Also known as Slipper Bearings, they guide moving parts along a path.	
	Cam follower	Rolling type of bearing that is used to guide objects along a designated path.
	Linear	This bearing type is designed to control friction and heat along an axis of a shaft or other non-round length of material.
Plain	Used to support a rotating shaft or journal. This type of bearing does not include rolling elements.	
	Journal	Similar to a sleeve bearing but covers less than 180° of a shaft or journal (a finely polished surface on a shaft). They usually comes in pairs. This type of bearing relies on oil or grease to control friction and heat.
	Sleeve	Hallow cylindrical bearing made of bronze or other material with bearing properties.
	Self-lubricating	Can be a sleeve or other shaped bearing with surfaces impregnated with a lubricating material.
Standard (Radial)	Designed to support radial loads impacted perpendicular to a shaft.	
	Ball	The most common type of bearing that use spherical balls to reduce the effects of friction.
	Roller	Uses rollers to reduce the effects of friction for heavy loads.
	Needle	Uses narrow cylinders, needles, to reduce the effects of friction for heavy loads over over a longer distance. Can be more narrow than ball or roller bearings.
	Angular Contact	Uses spherical balls or rollers (tapered) to reduce the effects of friction in radial and axial directions.

Primary Bearing Types	Secondary Type	Description
Thrust	Designed to support axial load impacted along and parallel with the shaft.	
	Ball	Uses spherical balls to reduce the effects of friction.
	Roller	Uses rollers to reduce the effects of friction.
	Needle	Uses narrow cylinders, needles, to reduce the effects of friction and bearing thickness.
	Angular Contact	Uses spherical balls or rollers to reduce the effects of friction in axial and radial directions.

Many bearings are available which use a combination of bearing types in one housing. These designs can handle bearing loads from several directions. Many mechanical systems use multiple bearings to control and stabilize rotary motion.

PLAIN BEARINGS

As will be discussed later, plain bearings are those bearings with non-rolling elements. They can be machined from cast or solid material. A common material used is continuous cast C93200 (SAE 660) bronze for superior quality and performance. The continuous casting process assures a uniform bronze structure throughout the bearing that is free from porosity and hard particle inclusions commonly found in other cast processes.

Plain bearings have been around since before the automobile. In the late '20s, a group of Chrysler engineers wanted a heavy duty self-lubricating bearing and developed a way of using sintered metal with oil that met their goal. Many variations have been developed since as shown in Table 4. {3}[7]

Table 4: *Typical Properties of Plain Bearings*

Plain Bearing Properties[1]	C93200; SAE 660	SAE 841 Bronze	SAE 863	Nylon
COMPOSITION–PERCENT				
Carbon	–	1.75 max.	–	–
Copper	81.0 – 85.0	87.5 – 90.5	18.0 – 22.0	–
Iron	–	1.0 max.	Balance	–
Lead	6.0 – 8.0	–	–	–
Tin	6.3 – 7.5	9.5 – 10.5	–	–
Zinc	2.0 – 4.0	–	–	–
Acid Insolubles (maximum)	–	–	–	–
Magnesium	–	–	–	–
Total Other Elements (maximum)	–	0.5	2.0	–
Balance	–	–	–	–
PHYSICAL AND MECHANICAL PROPERTIES				
Density (gm per cu. cm)	–	6.4 – 6.8	5.8 – 6.2	–

Plain Bearing Properties[1]	C93200; SAE 660	SAE 841 Bronze	SAE 863	Nylon
Elongation (% in one inch)	10%	1%	1%	–
"K" Strength Constant	–	26,500	30,000	–
Max[2,3] P	4,000	2,000	–	3,000
Max[2,3] V	750	1,200	–	450
Max[2,3] PV	75,000	50,000	–	17,000
Porosity (% Oil by volume)	–	19% min.	19% min.	–
Temperature, Max Operating	450°F (232°C)	10°F – 220°F	–	-20°F – 250°F (-28.9°C – 121°C)
Tensile Strength (psi/MPa)	35,000/	14,000/96.5	22,000/152	–
Yield Strength in Comp.[4] (psi/MPa)	20,000	11,000/75.8	22,000/152	–
COMPARABLE SPECIFICATIONS				
ASTM	B505 Type III	B438 Grade 1 Type II	B439 Grade 4	–
Military	**BEARINGS:**			
	–	MIL-B-5687D Type I Grade 1	MIL-B-5687D Type II Grade 4	–
	–	Formerly: MIL-B-5687C Type I Comp. A	Formerly: MIL-B-5687C Type II Comp. B	–
	BAR			
	–	Formerly: MIL-C-50709 Type II Grade 1	–	–
MPIF	–	CT-1000-K26	–	–
	–	Formerly: CT-0010-R	–	–

NOTE:
1 Bearings may exhibit appreciable differences in properties due to size, shape, thickness, etc.
2 All values are based on 72°F (22.2°C) room temperature and the standard lubricate for the bearing listed. The values for V can be increased by using special lubrication techniques.
3 Values for teflon bearings are approximately double that of nylon.
4 For 0.001 inch permanent set on test specimens 1-1/4″ diameter x 1″ long.

PV Calculation

Calculating Plain Bearing PV for a Sleeve Bearing

PV is a unitless value that is used as a means of measuring the performance capabilities of plain bearings. The value of PV is obtained by multiplying the velocity (V) by the pressure (P) applied to the projected area of the bearing; each is first determined separately using the following procedure. {3}[7]

Step	Action / Results	Supporting Information
1.	Determine sleeve bearing pressure (P): $$P_{Sleeve} = \frac{L}{A} = \frac{L}{l \times D}$$	Where: P_{Sleeve} = Pressure applied to bearing L = Load exerted on bearing A = Inside area of bearing l = Length of sleeve bearing D = Inside Diameter of bearing
2.	Determine sleeve bearing velocity (V): $$V = \frac{\pi}{12} S = 0262S$$	Where: V = Velocity of shaft wear surface against bearing ID (surface feet per minute or sfpm) 0.262 = Constant derived from an average. S = Rotational speed of shaft (RPM)

PV Calculation

Calculating Plain Bearing PV for a Sleeve Bearing		
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Step	**Action / Results**	**Supporting Information**
3.	Calculate PV: $PV = P \times V$	Where: PV = Unitless value previously defined P = Value calculated in step 1 V = Value calculated in step 2
End of procedure		

PV Example: Determine the PV for a 3/4" shaft rotating at 341 RPM in a sleeve bearing. The shaft weighs 90 lb total load. The bearing length is 1". Using the above procedure:

1. Applied pressure:
$$P = \frac{L}{l \times D} = \frac{90\ lbs}{1" \times 0.75"} = 120\ lb/in^2$$
2. Bearing wear velocity at shaft contact point:
V = 0.262 x RPM x shaft diameter, or 0.262 x 341 x 0.750 = 67 sfpm
3. PV = 120 psi x 67 sfpm = 8040 PV

Plain Bearing Tolerances

Plain bearings are typically machined from cast metal, plastic, or other material. If manufactured to standards specified in Table 12, tolerances are predetermined for stock plain bearings. [7]

Table 5: *Plain Bearing Tolerances*

Dimension	Criteria	Cast Bronze	Powered Bronze	Nylon
	in (mm)	in (mm)	in (mm)	in (mm)
Inside Diameter	3″ or less	±0.0010 (±0.0254)	–	–
	Over 3″	±0.0015 (±0.0381)	–	–
Outside Diameter	3″ or less	+0.002 – 0.003 (0.0508 – 0.0762)	–	–
	Over 3″	+0.003 – 0.005 (0.0762 – 0.127)	–	–
Inside Diameter or Outside Diameter	– 0.5	–	–	±0.002
	0.5 – 1.0	–	–	±0.003
	1.0 –	–	–	±0.004
	– 1.510 (– 38.4)	–	-0.001 (-0.0254)	–
	1.511 – 2.510 (38.4 – 63.8)	–	-0.0015 (-0.0381)	–
	2.511 – 3.010 (63.8 – 76.5)	–	-0.002 (-0.0508)	–
	3.011 – 4.010 (76.5 – 102.0)	–	-0.003 (-0.0762)	–
	4.011 – 5.010 (102.0 – 127)	–	-0.004 (-0.102)	–
Length		±0.005 (±0.127)	–	+0.015
	– 1.495 (– 38.0)	–	±0.005 (±0.127)	–
	1.496 – 2.990 (38.0 – 75.9)	–	±0.0075 (±0.190)	–
	2.991 – 4.895 (75.9 – 124.0)	–	±0.010 (±0.0254)	–

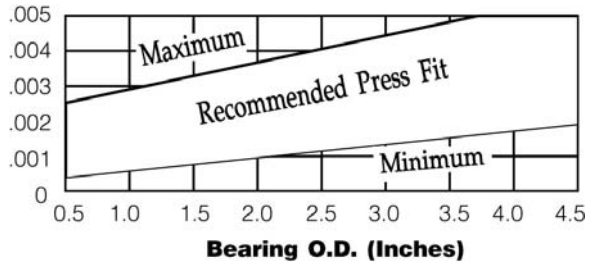
Dimension	Criteria	Cast Bronze	Powered Bronze	Nylon
	in (mm)	in (mm)	in (mm)	in (mm)
Concentricity		0.003 (0.0762) T.I.R	–	+0.003 – 0.005 (0.0762 – 0.127)
	Varies with wall thickness	–	0.003 – 0.007	–

Cast Bronze Bearings

As was expressed previously for tolerances, plain bearing standards define acceptable limits for bearing press fit and clearance. The figures in this section provide a simple means of estimating these values.

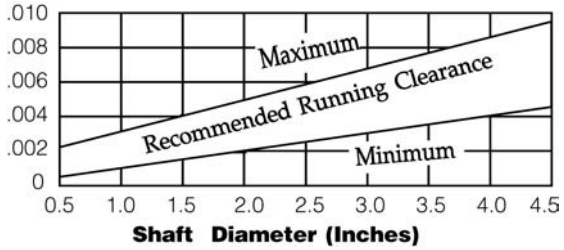
Figure 2 can be used as general reference to determine a good bearing fit when designing and selecting a C93200 cast bronze bearing or equivalent. A less than normal press fit can be satisfactory, if: 1) the bearing is long and the wall is not exceptionally thin and 2) the bearing is also carrying a moderate load exerted only in one direction. [7]

Figure 2: *C93200 Cast Bronze Bearing Press Fit*



A greater than normal clearance, Figure 3, must be allowed if: 1) exceptionally high speed is involved or 2) higher than normal loading is encountered. [7]

Figure 3: *C93200 Cast Bearing Clearance*



ROLLER BEARINGS

Unlike plain bearings, roller bearings have rolling elements. Typical elements include a spherical ball, cylindrical, needle, or tapered roller. Rolling elements are generally hardened metal, but can be made of non-metal materials, such as ceramic or delrin. As with most industrial parts and supplies, the design and manufacture of roller bearings is engineered according to standards listed in Table 12. Much of this section includes some of the basics, for roller bearings. If more detailed information is desired, refer to reference manuals listed in Table 41.

Roller Bearings Tolerances

ANSI/ABMA ABEC and RBEC address have addressed the above issues by developing precision bearing standards that define bearing grades and tolerances. The standards describe minimal tolerances and material properties to ensure bearing manufacturers follow strict specifications. The standards include:

Ball	Grade	This specifies dimensional and tolerance form, surface roughness, and sorting tolerance for balls used in bearings. ABMA tolerances are listed in Table 7.
	Sizing	Adhering to limits on bearing ball diameter variation ensures ball manufactures produce quality balls and ball sets.
	Sets	As bearings require a set of balls to function, to ensure optimal performance, diameter variation for all balls in the set, or lot, must meet ABMA tolerances.
	Spherical Form	Ball roundness variation is also controlled by ABMA limitations. This limitation is the difference between the smallest and largest ball diameter for a single ball.
	Surface Roughness (Ra)	Surface irregularities define ball roughness. This specification limits these measurable regularities, in microns.
Inner and Outer Ring	Ring Bore Limits	Inner and outer ring ID and OD, respectively, are limited by ABMA specifications. Some of these tolerances are listed in Table 8.
	Runout	Ring bore limits include Inner and Outer ring radial runout, axial runout, and width.

Classes of Tolerance for Roller Bearings

The ABEC scale is a system for rating the manufacturing tolerances of "precision" bearings. The system was developed by the Annular Bearing Engineering Committee or Council (ABEC) of the American Bearing Manufacturers Association (ABMA). They are rated with a number from 1 to 9, with the higher number assigned to bearings manufactured against a higher standard of precision (high number = tighter tolerances = more expensive bearing).

Table 6: *Tolerance Classes of Bearings – Cross Reference*

Bearing Standard[1]		Tolerance Class[2]					Bearing Types
ABMA ANSI	ABMA/ANSI Std. 20	ABEC-1 RBEC-1	ABEC-3 RBEC-3	ABEC-5 RBEC-5	ABEC-7	ABEC-9	Radial bearings (except tapered roller bearings)
	ABMA/ANSI Std. 19.1	Class K	Class N	Class C	Class B	Class A	Tapered roller bearings (Metric series)
	ABMA B 3.19 ANSI Std. 19	Class 4	Class 2	Class 3	Class 0	Class 00	Tapered roller bearings (Inch series)
	ABMA/ANSI Std. 12.1	–	Class 3P	Class 5P Class 5T	Class 7P Class 7T	Class 9P	Precision instrument ball bearings (Metric series)
	ABMA/ANSI Std. 12.2	–	Class 3P	Class 5P Class 5T	Class 7P Class 7T	Class 9P	Precision instrument ball bearings (Inch series)
ISO	ISO 492	Normal class Class 6X	Class 6	Class 5	Class 4	Class 2	Radial bearings
	ISO 199	Normal class	Class 6	Class 5	Class 4	–	Thrust ball bearings
	ISO 578	Class 4	–	Class 3	Class 0	Class 00	Tapered roller bearings (Inch series)
	ISO 1224	–	–	Class 5A	Class 4A	–	Precision instrument bearings
JIS	JIS B 1514	Class 0 Class 6X	Class 6	Class 5	Class 4	Class 2	All types
DIN	DIN 620	P0	P6	P5	P4	P2	All types

NOTE: [1] For a list of standards and titles, refer to Table 1 and Table 2.
[2] "ABEC" applies to ball bearings. "RBEC" applies to roller bearings.

Figure 4 shows a cross-sectional view of a typical bearing with dimensional designations. Refer to this figure as needed when using AMBA tolerance Table 7 and Table 8.

Figure 4: *Typical Ball Bearing Cross Section View*

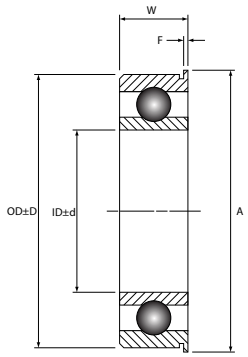


Table 7: *ABMA Bearing Ball Grades*

ABMA Grade[1]	Ball Diameter Variation	Deviation from Spherical Form	Lot Diameter Variation	Surface Roughness[2]
	in. (µm) V_{DS}	in. (µm) W	in. (µm) V_{DL}	**(Ra)** µ-in. (µm)
3	0.000003 (0.08)	0.000003 (0.08)	0.000005 (0.13)	0.5 (0.012)
5	0.000005 (0.13)	0.000005 (0.13)	0.000010 (0.25)	0.8 (0.02)
10	0.000010 (0.25)	0.000010 (0.25)	0.000020 (0.50)	1.0 (0.025)
15	0.000015 (.38)	0.000015 (.38)	0.000030 (0.76)	1.0 (0.025)
16	0.000016 (0.4)	0.000016 (0.4)	0.000032 (0.8)	1.0 (0.025)
20	0.000020 (0.5)	0.000020 (0.5)	0.000039 (1.0)	1.6 (0.04)
24	0.000024 (0.6)	0.000024 (0.6)	0.000048 (1.2)	2.0 (0.05)
40	0.000039 (1.0)	0.000039 (1.0)	0.000079 (2.0)	3.0 (0.08)
48	0.000048 (1.2)	0.000048 (1.2)	0.000096 (2.4)	3.0 (0.08)
60	0.000059 (1.5)	0.000059 (1.5)	0.000118 (3.0)	3.7 (0.095)
80	0.000079 (2.0)	0.000079 (2.0)	0.000157 (4.0)	4.7 (0.12)
100	0.0001 (2.5)	0.0001 (2.5)	0.000200 (5.0)	5.0 (0.125)
200	0.0002 (5.0)	0.0002 (5.0)	0.000400 (10)	8.0 (0.2)
300	0.000295 (7.5)	0.000295 (7.5)	0.000591 (15)	–
500	0.0005 (13)	0.0005 (13)	0.00100 (25)	2000 (50.8)

ABMA Grade[1]	Ball Diameter Variation	Deviation from Spherical Form	Lot Diameter Variation	Surface Roughness[2]
	in. (µm) V_{DS}	in. (µm) W	in. (µm) V_{DL}	**(Ra)** µ-in. (µm)
800	0.000787 (20)	0.000787 (20)	0.00157 (40)	–
1000	0.0010 (25)	0.0010 (25)	0.002 (50)	–
2000	0.002 (50)	0.002 (50)	0.004 (100)	5000 (127)
3000	0.003 (76)	0.003 (76)	0.006 (152)	–

NOTE: [1] Reference ISO 3290-2001 and ABMA 10-1989
[2] Some Ra values for grades above 200 are not available.

Table 8: *Ball Bearing Tolerances*

Outer Ring Tolerances {3}[4]

Outer Ring OD	Outer Ring OD Tolerance, D				Outer Ring Runout, W				Flange Diameter[1], A				Flange Thickness[1], F			
in (mm)	ABEC 1	ABEC 3	ABEC 5	ABEC 7	ABEC 1	ABEC 3	ABEC 5	ABEC 7	ABEC 1	ABEC 3	ABEC 5	ABEC 7	ABEC 1	ABEC 3	ABEC 5	ABEC 7
0.0–0.7087 (0–18)	+.0000 -.0003	+.0000 -.0003	+.0000 -.0002	+.0000 -.0002	+.0000 -.0050	+.0000 -.0050	+.0000 -.0010	+.0000 -.0010	–	+.0050 -.0020	+.0000 -.0010	+.0000 -.0010	–	+.0000 -.0020	+.0000 -.0020	+.0000 -.0020
0.7088–1.1811 (18–30)	+.0000 -.0004	+.0000 -.0003	+.0000 -.0002	+.0000 -.0002	+.0000 -.0050	+.0000 -.0050	+.0000 -.0010	+.0000 -.0010	–	+.0050 -.0020	+.0000 -.0010	+.0000 -.0010	–	+.0000 -.0020	+.0000 -.0020	+.0000 -.0020
1.1811–1.9685 (30–50)	+.0000 -.0005	+.0000 -.0003	+.0000 -.0002	+.0000 -.0002	+.0000 -.0050	+.0000 -.0050	+.0000 -.0010	+.0000 -.0010	–	+.0050 -.0020	+.0000 -.0010	+.0000 -.0010	–	+.0000 -.0020	+.0000 -.0020	+.0000 -.0020
1.9686–3.1496 (50–80)	+.0000 -.0005	+.0000 -.0004	+.0000 -.0003	+.0000 -.0002	+.0000 -.0050	+.0000 -.0050	+.0000 -.0015	+.0000 -.0010	–	–	–	–	–	–	–	–
3.1496–4.7244 (80–120)	+.0000 -.0006	+.0000 -.0005	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Inner Ring Tolerances {3}[4]

Inner Ring Bore ID	Inner Ring Bore Diameter Tolerance, d				Inner Ring Runout, W			
in (mm)	ABEC 1	ABEC 3	ABEC 5	ABEC 7	ABEC 1	ABEC 3	ABEC 5	ABEC 7
0.0–0.3937 (0–10)	+.0000 -.0003	+.0000 -.0003	+.0000 -.0002	+.0000 -.0002	+.0000 -.0004	+.0000 -.00025	+.0000 -.0010	+.0000 -.0010
0.3938–0.7087 (10–18)	+.0000 -.0003	+.0000 -.0003	+.0000 -.0002	+.0000 -.0002	+.0000 -.0004	+.0000 -.0003	+.0000 -.0010	+.0000 -.0010
0.7088–1.1811 (18–30)	+.0000 -.0004	+.0000 -.0003	+.0000 -.0002	+.0000 -.0002	+.0000 -.0005	+.0000 -.0003	+.0000 -.0010	+.0000 -.0010
1.1812–1.9586 (30–50)	+.0000 -.00045	+.0000 -.0004	+.0000 -.0002	+.0000 -.0002	+.0000 -.0006	+.0000 -.0004	+.0000 -.0010	+.0000 -.0010
1.9586–3.1496 (50–80)	+.0000 -.0006	+.0000 -.00045	–	–	+.0000 -.0008	+.0000 -.0004	–	–

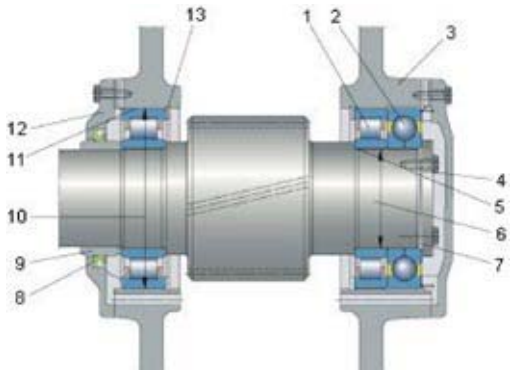
NOTE: [1] Only applies to ball bearings with an optional flange.

Bearing Components

To help in the selection, design, application, and operation of roller bearings; a basic understanding of standard bearings is required. A great place to begin is with the understanding of bearing nomenclature and components. The figures in this sections include number bearing components and a visual location and function for each. Some of the terms included can be found among bearing standards listed in Table 12; others may be manufacture specific. Those included in this section are compliments of SKF USA Inc. [3]

Figure 5 includes bearing and housing nomenclature that apply to a typical radial bearing application. It should be noted that this multi-bearing application includes bearings with both radial and axial load considerations. [3]

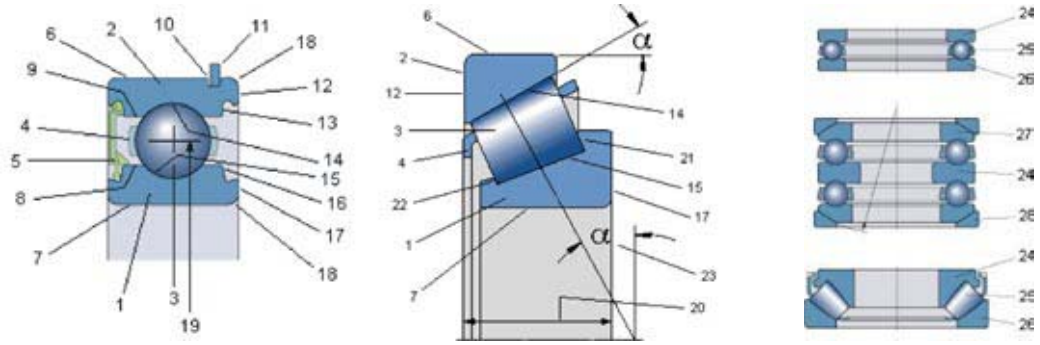
Figure 5: *Radial Bearing Components*



1. Cylindrical roller bearing
2. Four-point contact ball bearing
3. Housing
4. Shaft
5. Shaft abutment shoulder
6. Shaft diameter
7. Locking plate
8. Radial shaft seal
9. Distance ring
10. Housing bore diameter
11. Housing bore
12. Housing cover
13. Snap ring

Individual bearing components are located and listed in Figure 6. Review these components to gain a better understanding of basic and optional bearing parts. [3]

Figure 6: *Bearing Components*



1. Inner ring
2. Outer ring
3. Rolling element: ball, cylindrical roller, needle roller, tapered roller, spherical roller
4. Cage
5. Capping device
   - **Seal** – made of elastomer, contact (shown in figure) or non-contact
   - **Shield** – made of sheet steel, non-contact
8. Outer ring outside diameter
9. Inner ring bore
10. Inner ring shoulder diameter
11. Outer ring shoulder diameter
12. Snap ring groove
13. Snap ring
14. Outer ring side face
15. Seal anchorage groove
16. Outer ring raceway
17. Inner ring raceway
18. Sealing groove
19. Inner ring side face
20. Chamfer
21. Mean bearing diameter
22. Total bearing width
23. Guiding flange
24. Retaining flange
25. Contact angle

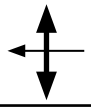
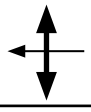
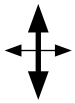
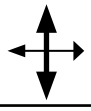
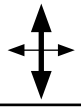
Roller Bearing Symbols

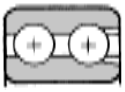
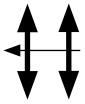
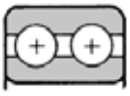
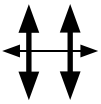
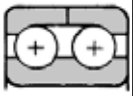
Most bearing symbols are defined by standards listed in Table 12. If a manufacturer produces a non-standard bearing, its symbol may be a modification of the standard version. When referencing bearings, as shown in Table 3 for ball-element bearings, documented media can include a bearing code and/or symbol. Bearing code syntax is as follows:

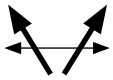
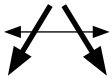
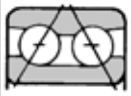
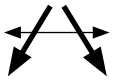
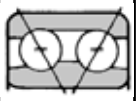
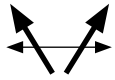
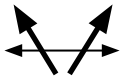
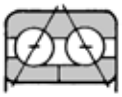
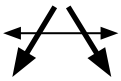
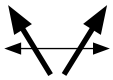
Bearing Type[1]		Feature(s)
B	Ball Element	1 or 2 characters Identify aspects of the bearing beyond basic design
N	Needle Roller	
R	Rolling Element	
S	Self-Aligning	
T	Thrust	

NOTE: [1] Refer to Table 3 to compare bearing element types.

Table 9: *ABMA Ball Bearing Codes and Symbols {3}[4]*

Bearing Type	ABMA Type Code	Symbol	Style[1]	Bearing Load[2] Primary Secondary	Comments
Deep groove Single-Row Radial contact	BC		Slot assembly, without filling slot		This is the simplest of ball bearing types. It includes a Single-Row of ball rolling elements sandwiched along a single, deep-groove, raceway.
	BH		Non-separable counter-bore assembly		
	BM		Separable assembly, may be disassembled		
	BL		BC type, with filling slot		Refer to Figure 7 for filling slot details.
Single-Row Angular contact Spherical outside surface	BCA		Spherical outside ring, without filling slot		
	BLA		Spherical outside ring, with filling slot		Refer to Figure 7 for filling slot details.

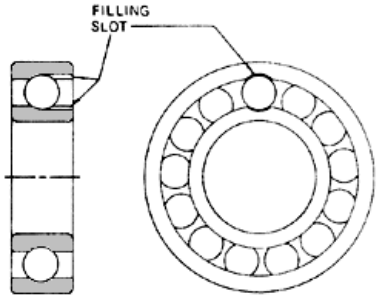
Bearing Type	ABMA Type Code	Symbol	Style[1]	Bearing Load[2] Primary Secondary	Comments
Single-Row Angular contact[3]	BA		Non-separable rings		Nominal contact angle from above 22° to, and including, 32°
	BAS		Separable inner ring		
	BT		Basic angular bearing Non-Separable		Nominal contact angle from above 32° to, and including, 45°
	BN		Non-separable		Nominal contact angle from above 10° to, and including, 22°
	BNS		Separable outer ring		
	BNT		Separable inner ring		
	BY		Two-piece outer ring		A split ring generated two contact points, one for each half of the ring.
	BZ		Two-piece inner ring		
Double-row Radial contact	BF		With filling slot		Refer to Figure 7 for filling slot details.
	BK		Basic bearing		
	BHA		Non-separable two-piece outer ring		A split ring generated two contact points, one for each half of the ring.

Bearing Type	ABMA Type Code	Symbol	Style[1]	Bearing Load[2] Primary Secondary	Comments
Double-row Angular contact[3]	BD		With filling slot		Vortex of contact angle is toward inside of bearing. Refer to Figure 7 for filling slot details.
	BE		With filling slot		Vortex of contact angle is toward outside of bearing. Refer to Figure 7 for filling slot details.
	BG		Without filling slot		Vortex of contact angle is toward outside of bearing.
	BJ		Basic bearing, without filling slot		Vortex of contact angle is toward inside of bearing.
	BAA		Non-separable two-piece outer ring		Vortex of contact angle is toward inside of bearing.
	BVV		Separable two-piece inner ring		Vortex of contact angle is toward outside of bearing.
Double-row Self-aligning[3]	BS		Spherical outer ring raceway		Vortex of contact angle is toward inside of bearing.

NOTE:
1. Most roller bearings include a cage that is not shown in the included symbols.
2. Arrows shown represent forces applied against the inner ring by the shaft. Refer to the Bearing Loads section for more details.
3. A line drawn through ball contact points forms an acute angle perpendicular to the bearing axis. Refer to Figure 12.

Many of the above bearing types included a filling slot. Figure 7 shows a more detailed illustration and explanation of a filling slot for radial bearings.

Figure 7: *Filling Slot Details*



Filling Slot –

As shown on the left, a filling slot is located at a single point between the inner and outer race. It allows for the insertion and removal of rolling elements. This is done by first aligning the slot of the inner ring with the opposing slot of the outer ring.

In the case of the image to the left, balls can be inserted or removed, through the slot, to increase or decrease radial load capacity.

A filling slot in a radial bearing reduces thrust load capacity.

Standard codes and symbols for roller, self-aligning, tapered, needle, and thrust bearings are available in reference manuals listed in Table 41.

Bearing Identification

ANSI/ABMA and ISO standards organizations are a few of the world wide standards that define bearing identification. However, because of the many types of bearings, it is sometimes difficult for manufacturers to apply standard bearing designations. In this case suffixes and/or prefix information are included.

This section lists some of the standard designations that exist for bearings, which are normally placed on the wider surface of the outer ring. If a replacement bearing does not match any of the designation information listed here, contact Customer Service for assistance.

Bearing designations fall into one of two groups: standard or special. Depending on the manufacturer, special bearing designations may or may not include, in part, standard designation information. Roller bearing designations will closely follow either ANSI/ABMA or ISO designation syntax and data. In most cases, ISO bearing designations are used. Information for both designation types are listed in this guide.

ANSI/ABMA Bearing Designation

There are many similarities between ANSI and ISO bearing designations. As a recommended standard, bearing manufacturers may include, modify or append to the standard designation system. Because manufactures design and build bearings that deviate from the standard or are custom, existing bearing designations may not apply. For more details, contact Customer Service.

Figure 8, along with Tables 10 and 11, include designation information for ANSI/ABMA bearings. Figure 8 shows a relationship between bearing sizes in OD and width. Exact dimensions are specified by the standard and manufacturer. {3}

Figure 8: *ANSI/ABMA Bearing Dimension Codes*

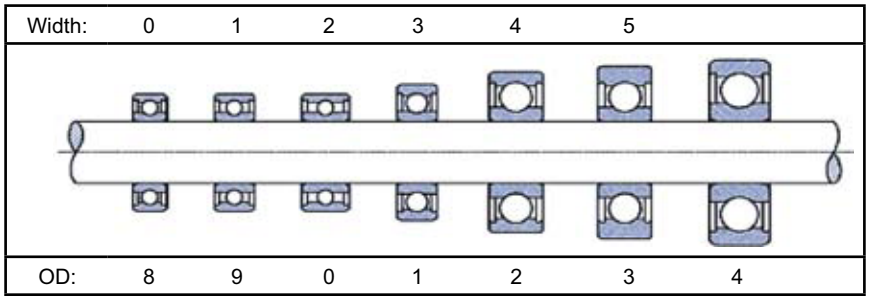


Table 10: *Typical ANSI/ABMA Ball Bearing Numbering*

A – Syntax[1]

Code:	Bore	Type	Width & OD	Options	Internal Fit
Digits[2]:	000	AAA	00	AAAA	0
Table:		13 (same as ISO)	Figure 8	10–B	

B – Definitions

ABMA Code	# Digits	Options	Description
Bore	1, 2, or 3	Dimension	Inside diameter of bearing in mm.
Type	1, 2, or 3	From Table 3	One, two or three letter code identifying the type of bearing.
Width & OD	1 or 2 See Figure 8	00	6000 series
		02	6200 series
		03	6300 series
		04	6400 series

ABMA Code	# Digits	Options	Description
Options	1, 2, or 3	X	Manufacturer a standard bearing cage
		P	Metal shield permanently fastened
		S	Contact seal permanently fastened
		G	Snap ring groove on O.D. with snap ring
Internal Fit	1	3	An internal clearance greater than standard

NOTE: [1] Manufactures my include this information in their numbering system, but may change the order listed, add more options, etc.
[2] AMBA bearing numbers are always arranged as number/letter/number/letter/number....

Table 11: *Typical Bearing Designation Samples*

Prefix[1]	Space or non-separated	Basic Designation[2]	Space, Oblique stroke or hyphen	Suffix[3]
R		NU 2212		ECML
W		6008	/	C3
		23022	–	2CS

NOTE: [1] Manufacture dependant information defining bearing attributes. In most cases, letter codes are used and could include information for sealed, hybrid, shielded bearings. It can also specify if inch or metric dimension apply.
[2] This could be ANSI/ABMA or ISO designation standard. Refer to Table 12 to Table 15 for more details.
[3] Suffix designations are assigned by the manufacture and may include ISO suffix data listed in Table 16. Suffix data may include information about internal and external design, cage designations, materials, clearance specifications, bearing sets, lubrication, etc.

Table 11 includes some possible examples of bearing designations. As stated previously, each bearing manufacturer's designation syntax will be different and relative to the type and style of bearing offered. The table shows a prefix, that further identifies bearing type, and a suffix that specifies bearing attributes.

ISO Bearing Designation

ISO basic bearing designation includes data listed in Table 12 to Table 15.

Table 12: *Basic ISO Ball and Roller Bearing Designations*

ISO Bearing Syntax[1]

Code:	Bearing Series		Bore Size
	Type	Dimension Series	
Digits[2]:	X	YY	ZZ
Table:	13	14	15

Examples: **6204**

The first digit in Table 12, represents the bearing type. In the example (**6**204), the **6** represents a single-row ball bearing.

Although shown as a single digit, this value can be any combination up to 3 numbers and/or letters. Bearing manufactures may use letter values to expand the ISO standard. Common bearing types are listed in Table 13.

Table 13: *ISO Ball and Roller Bearing Series Designation – Part 1*

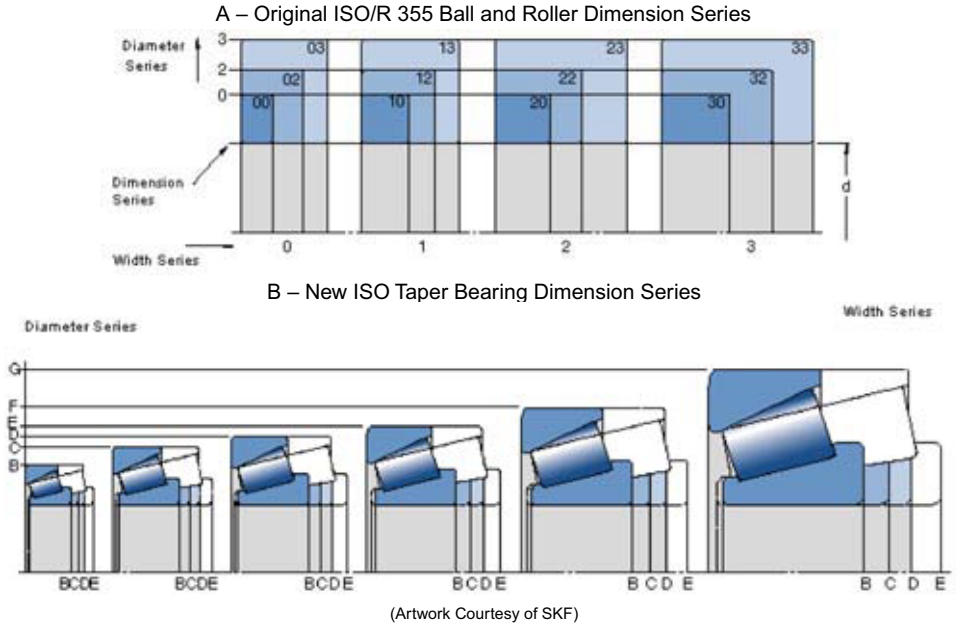
Digits	ISO Code	Bearing Type Description
1st Digit - Numerical	0	Double-row angular contact ball bearings
	1	Ball bearing – double-row, self-aligning
	2	Ball bearing – double-row, wide self-aligning (may also represent spherical roller bearing and spherical roller thrust bearings)
	3	Angular contact ball bearing – double-row (may also be for tapered roller bearings)
	4	Ball bearing – double-row deep-groove
	5	Thrust ball bearing
	6	Ball bearing – single-row deep-groove
	7	Angular contact ball bearing – single-row **719** = ISO Dimension Series 19 **70** = ISO Dimension Series 10 **72** = ISO Dimension Series 02
	8	Thrust bearings – cylindrical roller
Sample Letter Codes[1] for 1st digit	C	CARBTM™ toroidal roller bearing
	N	Cylindrical roller bearings A second and sometimes a third letter are used to identify the configuration of the flanges, e.g. NJ, NU, NUP; double or multi-row cylindrical roller bearing designations always start with NN.
	NA	Needle roller bearings with boundary dimensions to ISO 15
	NK	Needle roller bearing
	QJ	4-point contact ball bearings
	T	Tapered roller bearings, a few metric sizes to ISO 355-1977.[2]

NOTE: [1] These letter codes are for SKF bearing types and may be different for other vendors.
[2] Inch tapered roller bearings with dimensions to an ABMA series are designated according to a different system to ANSI-ABMA Standard 19.

The second and third, of five digits, represent the ISO Bearing Series designation. In the examples, **20** represents a width of **2** and a relative diameter **0**, as shown in Figure 9 A.

These two digits are further divided into radial bearing width or thrust bearing height, depending on the bearing type specified, and the third digit representing a standard bearing diameter. Ball and roller radial and thrust bearing series designations are independent of the rolling element used. The presence of a "/", after the bearing type information, identifies a special size bearing.

Figure 9: *Standard ISO Bearing Dimension Series*



(Artwork Courtesy of SKF)

Table 14: *ISO Ball and Roller Bearing Series Designation – Part 2*

Digits		ISO Code	Digit		ISO Code
2nd digit	Radial Bearing Width or	8	3rd digit	Outside Diameter	7
		0			8
		1			9
		2			0
		3			1
		4			2
		5			3
		6			4
		9			
	Thrust Bearing Height	7			
		9			
		1			

The next two digits, in the basic ISO ball and roller designation, represents the ID (inside dimension), or bore size, of the inner ring, specified in metric units according to the next data table.

Table 15: *ISO Bearing Bore Sizes*

Digit	ISO Code	Description
4th & 5th digit	8	8 mm
	9	9 mm
	00	10mm
	01	12mm
	02	15mm
	03	17mm
	XX	04 to 64 for from 20 to 480mm bore bearings, represented in 5mm increments. To determine bore diameter, multiply the 2 digits by 5 mm. e.g. if the bearing number was 04 (04 x 5 = 20 mm), 05 (05 x 5 = 25 mm), etc.

The letters at the end of the number represent the bearing specialty. They will very among manufacturers and may include 1 to 4 letter/number combinations that are strung together and separated by a space. The codes can identify seals, shields, lube type, bearing angle (tapered bearings), bearing clearance, etc. Some examples are listed in the next table.

Table 16: *Typical Bearing Suffix*

Spaces	Codes	Description
1 or more Letters	CD	15 degree contact angle (for angular contact bearing)
	ACD	25 degree contact angle (for angular contact bearing)
	DDU	Double contact seals
	RS	Single sealed
	2RS	Double sealed
	V or N	Single non-contact seal
	VV, 2V, NN or 2N	Double non-contact seal
	Z	Single shielded
	ZZ or 2Z	Double shielded
	CX	Some manufactures include a value at the end of the bearing number representing ball clearance. Typical values are C1, C2, C3, C4, or C5 designations. This is the inner race to ball tolerance. Refer to Table 8.

As implied by the data tables previously listed in this section, you can learn a lot about a bearing just from its part number. A typical bearing is the 6203ZZ bearing.

Bearing designation = 6203ZZC3

Where:
- *6* = Type Code – single-row, deep-groove radial ball bearing
- *2* = Series – this is normally a two digit code (02), but in this case the (0) is omitted
- *03* = Bore – 17 mm
- *ZZ* = Suffix – double shielded
- *C3* = Bearing Clearance – larger than normal

Bearing Loads

All bearings are designed to reduce friction under load due to an applied force in one or more directions. Bearing types are categorized based on the direction of the load for which they are designed to handle. For instance, radial bearings are designed to handle loads applied radially to the shaft. The are loads applied perpendicular to the shaft. Thrust bearings are designed to handle axial loads that are applied parallel to the shaft centerline axis.

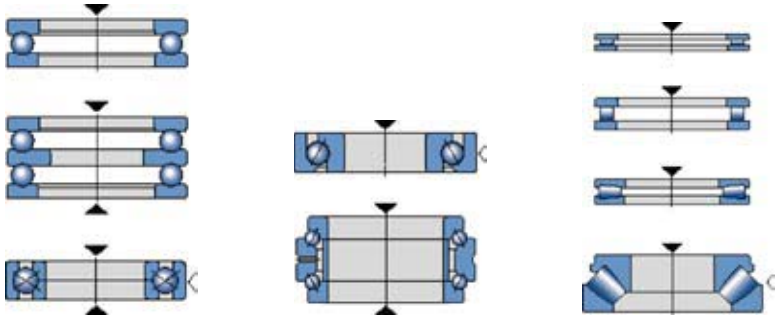
For every force applied to a bearing, there is an equal and opposite force applied against it (not shown in the previous figures). Bearings are typically designed to manage forces from particular directions where the outer and inner rings are independently supported. Most bearings are not designed to accept loads from the opposite direction. Installing a bearing backwards can cause a bearing to break apart under expected loads. Also, excessive loads applied in another direction can damage or shorten the life of a bearing.

The following four figures show various bearing types, represented pictorially, and the direction of the loads for which they are designed to manage.

Axial Loads

As previously stated, axial loads are those applied along a shaft. They are usually associated with thrust bearings that prevent a shaft from moving or sliding out of position. An example would be a drill motor whose chuck and spindle must resist damage from forces applied while the drill bit is machining a hole.

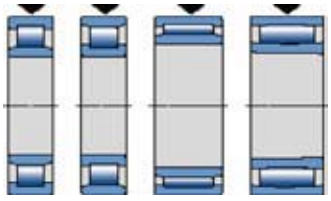
Figure 10: *Axial Bearing Load*



Radial Loads

A load applied to the side of a shaft that might cause the shaft to bend would be a radial load. The type of bearing used to resist such loads would depend on the magnitude of the load applied and the speed (RPM) at which the bearing is expected to move. In most cases, a roller or needle bearing is best because the contact point of the bearing element is a line, as opposed to a single point, established by a ball bearing.

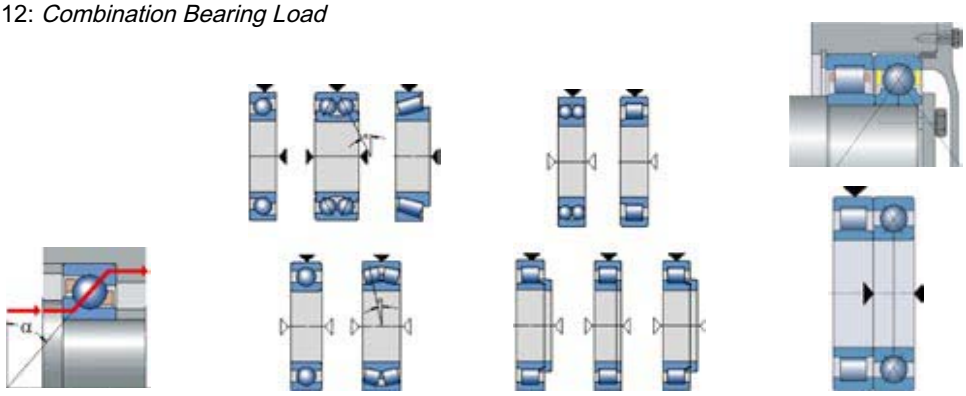
Figure 11: *Radial Bearing Load*



Combination Loads

In most applications, a shaft is subjected to loads from more than one direction. A CNC mill, lathe, or wood router (for example) plunges into raw material, then follows a specified lateral path to create the desired groove or shape. The wheel hub of a vehicle, or an amusement ride, radially supports its weight when parked and when moving, but as the car turns, inertial forces are exerted against the hub at an angle depending on the degree of the turn and the speed traveled. The following figure shows some bearing designed to manage loads from two directions.

Figure 12: *Combination Bearing Load*

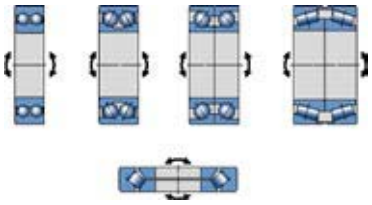


If a shaft must support loads from several directions, multiple bearings will be used in the application. Various bearings can be stacked or placed at the points along the shaft where the loads are applied. In some cases, custom bearings are used. In the case of an angular bearing, shown at the far left in the above figure, if the applied load is reversed, the bearing will likely break apart.

Moment Loads

Moment loads are rotary in nature and are applied in a way that would tilt and reorient a shaft's centerline. As shown in Figure 13, bearings, used to manage this type of load, usually have double row rolling elements. They can also be combined with other bearing types to manage loads from multiple directions.

Figure 13: *Moment Bearing Load*



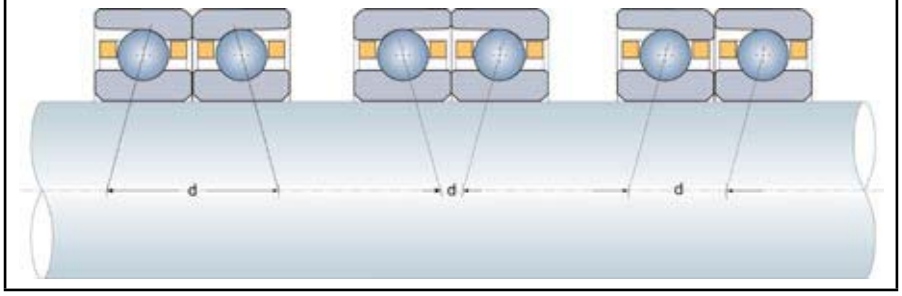
Matching Bearing Sets

Seldom is only one bearing used in an application where a rotating shaft must be supported and mechanically managed. As seen in the previous section on Bearing Loads, as individual components, bearings can manage one or two load types. Two or more bearing combinations may be required when loads must be managed from multiple directions or when a load is beyond the recommended limit for a singular bearing.

Duplex Set

One of the simplest and most popular uses of multiple bearings is the Duplex set as defined in Table 17.

Table 17: *Duplex Bearing Combinations*

Back-to-Back	Fact-to-Face	Tandem
• Symmetrical arrangement • Can manage both radial and axial loads in both directions • High moment rigidity	• Symmetrical arrangement • Can manage both radial and axial loads in both directions • Low moment rigidity	• Requires two identical bearings • Can manage one direction axial load, only • Requires preloading with springs
		

Multiple Set

Three or more bearings are used to increase load capacity beyond the limits of a duplex set. This could include any combination of back-to-back, face-to-face, and/or tandem bearings using the same considerations listed in Table 17. [3]

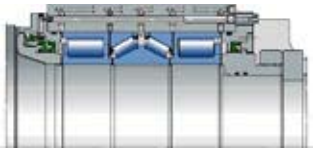
Combining Bearing Types

Duplex and Multiple set bearings primarily address shaft load and axial displacement issues. As stated previously, two or more bearings are typically required to support and manage a rotating shaft. As with any bearing application, the bearing supports the shaft and a housing supports the bearing. When loads must be managed from multiple directions, a housing must be designed to support each bearing used. This could be any combination of the bearings discussed in the previous section on Bearing Loads.

In such an application, the designer must design and manufacture the housing or housings to support the bearings and shaft. As can be seen in Figure 14, combination bearings are available that have the advantage of less engineering on the part of the designer, compact space, and, most likely, less cost.

Figure 14: *Combination Bearing Examples*

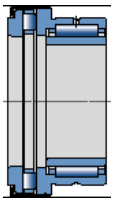
Combination cylindrical roller/ tapered roller



NOTE: This combination can be obtained by combining individual bearings or using a combination bearing.

Combination needle roller/ cylindrical roller thrust bearing

Same as above, with an inner ring



Combination needle roller/ angular contact ball bearing

Combination needle roller/ thrust ball bearing

For more information on combination bearing types, contact Customer Service.

LUBRICATION

Lubrication reverses the effects of friction and heat generation inside the bearing and protects metal surfaces against corrosion. Apart from the metal parts of a bearing, lubrication is the most important component in a bearing, especially when moving at high speeds. Two types of lubrication are used, grease and oil, that are applied using a variety of methods.

Lubrication Considerations

There is more to lubricants than just viscosity level. The type of lubricant and method of application and/or delivery is also very important and can make a big difference in bearing performance.

In the case of grease, most of the time it is sealed or injected into the bearing or bearing housing. Depending on the housing design, this means the bearing may need to be enclosed with seals on one or both sides. In some cases, heat lowers grease viscosity to a point where it can flow past seals and leak out. In this case regular maintenance may need to be scheduled.

Oil viscosity is typically lower than grease and more fluid. Therefore, the method of application is different. In most cases, oil passes over bearing components after being picked-up by or delivered to the bearing.

Some factors to determine the best lubrication type and method are listed in Table 18, while Table 19 compares grease and oil using the same factors.

Table 18: *Bearing Lubrication Considerations*

Lubricating Design Factor	Discussion
Load	Bearings support and locate rotating shafts and other devices. Mass and movement create forces that act on bearings and its components. The bearing must be strong enough to manage radial and/or axial loads.
Heat dissipation	As bearing speeds increase, the amount of heat generated is increased. If this heat cannot be dissipated, bearing operation and lubricant performance can be reduced to the point where components soften or weld together.
Lubrication	As seen in the section on Troubleshooting, the type and amount of lubrication is important. Both too much and too little lubrication can effect performance.
Maintenance	Except for self-lubricated bearings, maintenance is required to maintain lubricant levels, cleanliness and/or replacement.
Protection against contaminants	Contaminants can cause molecular breakdown of lubrications and degrade performance. There are many ways to ward off contaminants as discussed in several sections of this guide.
Speed	Friction and speed are closely related. As bearing speed increases, the churning effects increases the friction between lubricant molecules and moving parts, which generates more heat. To keep operating temperature low, friction must be minimized.
Viscosity	Much of this guide discusses the viscosity of lubricants. It is very important to select the lubricant with the correct viscosity for your application. The correct viscosity lubricant will form a fluid film between contact surfaces. This film prevents metal-to-metal contact between bearing components and minimizes friction. How effectiveness of this film depends on viscosity, load, and heat.

Table 19: *Grease vs. Oil*

Lubricating Design Factor	Grease	Oil
Load	Grease can protect moving parts under large loads. The protective film that forms on bearing surfaces resists compression because it is thicker than oil and the molecules are heavier.	The thin molecules of oil are less effective under heavy loads. This can be compensated by using more bearings and rolling elements with larger contact points or lines.
Heat dissipation	No heat is dissipated by grease, which normally stays inside the bearing and housing.	Depending on the the delivery method, as cool oil passes into, through, and out of the bearing, it caries away heat.
Lubrication	The thickness of grease goes a long way to control friction and lubricate moving parts.	The fluidity of oil makes it ideal for pumping. Circulated oil has the advantage of removing heat during circulation.

Lubricating Design Factor	Grease	Oil
Maintenance	Greases generally require less maintenance than oil, because it stays with the bearing and offers more protection against contamination and corrosion.	Oil requires more maintenance because it is more likely to escape through seals and circulation system adds equipment that increases the chance of failure.
Protection against contaminants	A grease filled bearing blocks contaminants from entering. Grease coated surfaces also prevent oxidation and corrosion.	Standing oil gradually thins as it flows from surfaces. The exposed surfaces can oxidize, inviting corrosion.
Speed	The churning action with speed tends to break-down molecular structure of grease. Grease also contains the heat. Grease is ideal for slow speeds.	Because oil molecules are already small, the churning effect of speed has less effect.
Viscosity	Fluid film on bearing elements forms faster with grease. Thick grease will not run off surfaces of a static bearing.	Although thinner than grease, oil has more advantages at high speeds.

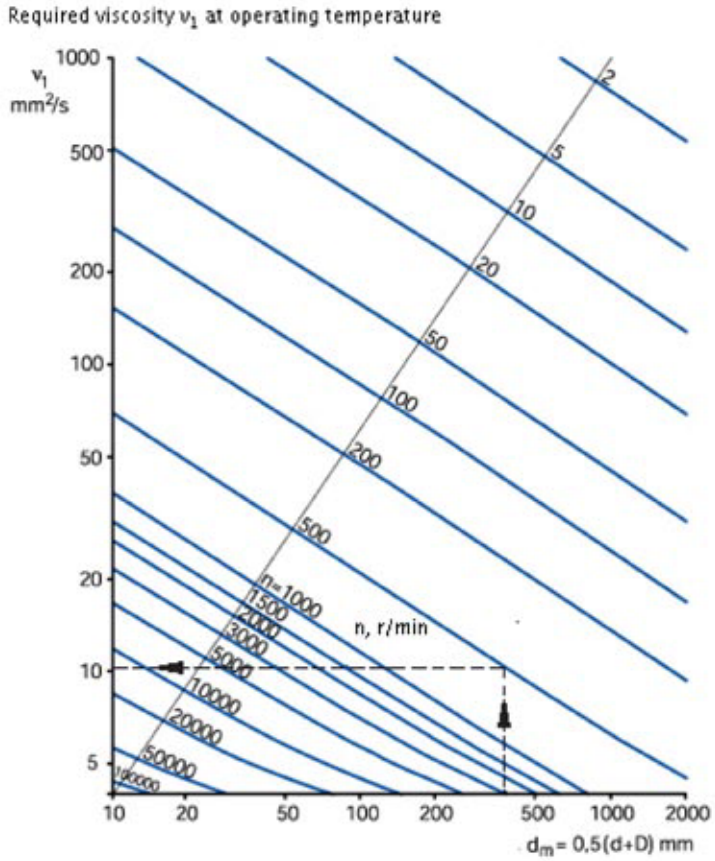
NOTE: Differences in the lubricating properties of seemingly identical lubricants – particularly grease – produced at different locations can exist. Therefore, Reid Supply cannot accept liability for any lubricant or its performance. The user is therefore advised to specify lubricant properties in detail so as to obtain the most suitable lubricant for the application.

Viscosity

Viscosity (ν) is the most important factor when determining the proper lubricant to be used. It determines how the lubricant will flow among moving elements in the bearing. It also determines a lubricants ability to maintain separation between two surfaces. A measure of this separation is the viscosity ratio (κ) or Kappa, discussed later.

It should be noted that many manufacturers include recommended lubricant information in the bearing ID. If not included or it is determined that the application calls for a different type of lubricant and/or lubricating method; use the figure below and the following procedure to determine a minimum lubricant viscosity for a bearing by size and speed. [3]

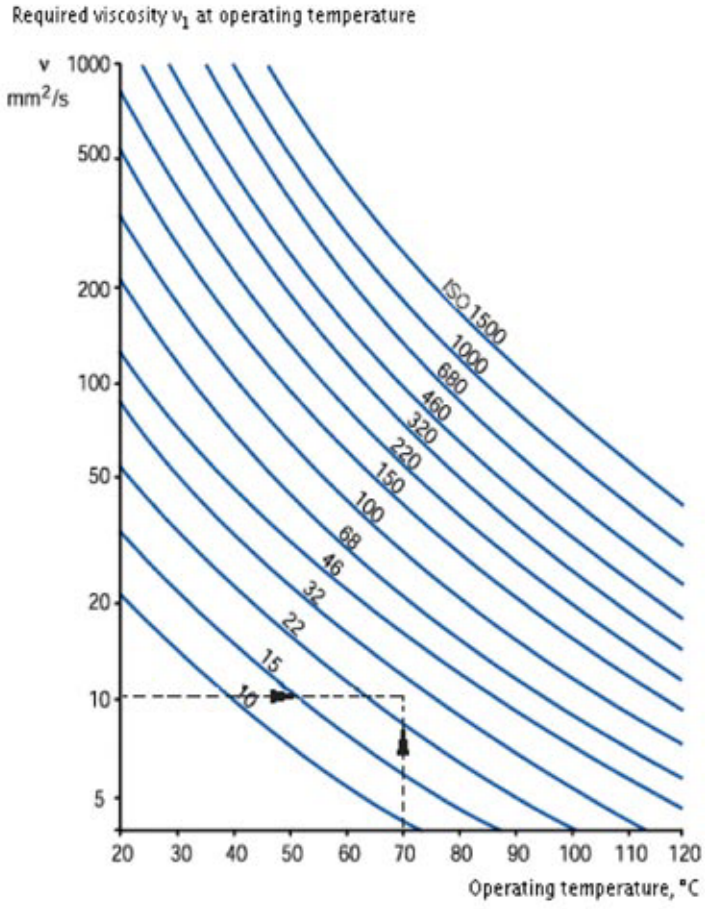
Figure 15: *Estimation of the Minimum Kinematic Viscosity at Operating Temperature*



Calculating Minimum Bearing Lubricant Viscosity		
Use this procedure to determine an acceptable lubricant viscosity for a bearing based on bearing specifications and operating speed. Figure 15 is required for this procedure.		
Step	**Action / Results**	**Supporting Information**
1.	Determine and record bearing ID and OD values.	Where: ID = Bearing inside bore diameter (mm). OD = Bearing outside diameter (mm). These values can be measured if bearing specifications are not available.
2.	Calculate bearing Mean Diameter (d_m) and record value. d_m=0.5(ID+OD)	
3.	Apply Step 2 results to Figure 15 to determine the value of v_1 for the next step.	To use chart (refer to example line in chart): A. Locate Step 2 value at bottom scale of chart. B. Follow a vertical straight line to intersection of the speed line drawn in the chart. C. Follow a horizontal straight line, from the intersection point of B, toward the v_1 vertical scale to the left. D. Record the value of the point where the horizontal line in C intersects with the v_1 scale.

Calculating Minimum Bearing Lubricant Viscosity		
4.	Use Figure 16 to select the best ISO classified lubricant, based on the value of Step 3 and the operating temperature. Record the ISO class found on the chart and use this value to select a lubricant for the bearing application.	To use chart (refer to example line in chart): A. Locate the operating temperature along the bottom scale. B. Trace a vertical line straight upward toward the lines drawn in the chart for ISO classifications. C. Locate v_1 value, determined with Step 3, along the left vertical scale. D. Trace a horizontal straight line to the right toward the line traced in B. E. Observe the intersection point of the lines traced in B and D. Record the ISO classification for the first line up from the intersection point.
End of procedure		

Figure 16: *Kinematic Viscosity to ISO Class at Operating Temperature*



ISO Lubricant Classification

Table 20, lists recommended lubricant viscosity for ISO 3448 lubricant grades shown in Figure 16. These values are for a standard operating temperature of 40°C.

Table 20: *ISO 3448 Viscosity Classification*

Viscosity grade	Kinematic Viscosity at 40 °C (mm²/s)		
	mean	min	max
ISO VG 2	2.2	1.98	2.42
ISO VG 3	3.2	2.88	3.52
ISO VG 5	4.6	4.14	5.06
ISO VG 7	6.8	6.12	7.48
ISO VG 10	10	9.00	11.0
ISO VG 15	15	13.5	16.5
ISO VG 22	22	19.8	24.2
ISO VG 32	32	28.8	35.2
ISO VG 46	46	41.4	50.6
ISO VG 68	68	61.2	74.8
ISO VG 100	100	90.0	110
ISO VG 150	150	135	165
ISO VG 220	220	198	242
ISO VG 320	320	288	352
ISO VG 460	460	414	506
ISO VG 680	680	612	748
ISO VG 1.000	1,000	900	1,100
ISO VG 1,500	1,500	1,350	1,650

Kappa

The previous discussion provides information to determine a minimum kinematic viscosity for a bearing based on size and speed. However, as with most design considerations, a design factor should be added to minimum values to compensate for fluctuations and/or unforeseen factors. For lubricants, this design factor is kappa (κ). Kappa is the ratio of the specified viscosity for the lubricant to be used in an application compared to the minimum kinematic viscosity determined using Figure 15. The formula for kappa is:

Eq. 1: *Determine Viscosity Ratio (κ)*

$$\kappa = \nu / \nu_1$$

Where:
- κ = Viscosity ratio.
- ν = Operating viscosity of lubricant (mm²/s)
- ν_1 = Rated viscosity depending on the bearing mean diameter and operating speed.

The chart in Figure 16 is used to select an ISO lubricant class that most closely matches ν^1 that would likely produce a kappa value slightly greater than one (meeting minimum requirements). Bearing manufactures recommend a kappa value between two and four where a lubricant is most likely to protect bearing components in the case of vibration, impact, contaminants and other factors. Kappa values above 4 are likely to have little or no performance improvement. Table 21 lists recommended viscosity levels for common bearing bore sizes and motor speeds.

Table 21: *Lubricant Viscosity at Common Motor Speeds*

Bearing Bore	Bearing Speed (RPM)				
mm	10,000	3,600	1,800	600	50
4–7	68	150	220		
10–20	32	68	150	220	460
25–45	10	32	68	150	320
50–70	7	22	68	150	320
75–90	3	10	22	68	220
100	3	7	22	68	220

nDm

Table 22 lists maximum lubricated bearing speeds by type. The values specified are calculated using the following formula:

Eq. 2: *Bearing Speed Formula (nDm)*

$$nDm = n \times d_m$$

Where: nDm = A unitless value that will give an indication of the relative speed of rotation (RPM) to the physical size of a bearing.

n = Bearing operating speed (RPM).

d_m = Bearing mean diameter. This value calculated using the equation $d_m = 0.5(ID+OD)$ used in the procedure "Calculating Minimum Bearing Lubricant Viscosity".

Table 22: *Maximum Bearing Speeds*

Bearing Type	Oil Lubricated	Grease Lubricated
Radial ball bearings	500,000	340,000
Cylindrical roller bearings	500,000	300,000
Spherical roller bearings	290,000	145,000
Thrust ball or roller bearings	280,000	140,000

From Handbook of Lubrication and Tribology, Volume 1, Second Edition by George E. Totten

As can be determined, large bearings moving at high speeds will have a high nDm, which is directly proportional to bearing size and shaft speed. As nDm increases, lubricant churning is more dramatic and thickener degradation increases relative to the bearing rolling element type. Increased nDm can have the effect of hardening or softening lubricant, depending on the type.

It should be noted that this is one case where the standards have not caught up with technology, bearing design, available lubricants, and lubrication methods. Some bearings, with synthetic lubricants, can result in bearings functioning at a nDm up to 2,000,000. nDm values up to 4,000,000 may be possible with oil or air jet lubrication. Contact Customer Service for more information.

For comparison purposes, Table 23 shows the kinematic value (v_1) for common lubricants and fluids.

Table 23: *Kinemitic Value (v_1), listed a CentiStokes for Common Lubricants and Fluids*

Fluid	Temperature		Kinematic Viscosity
	(°F)	(°C)	CentiStokes (cSt)
Acetaldehyde CH3CHO	61 68	16.1 20	0.305 0.295
Acetic acid - vinegar - 10% CH3COOH	59	15	1.35
Acetic acid - 50%	59	15	2.27

Fluid	Temperature		Kinematic Viscosity
	(°F)	(°C)	CentiStokes (cSt)
Acetic acid - 80%	59	15	2.85
Acetic acid - concentrated glacial	59	15	1.34
Acetic acid anhydride (CH3COO)2O	59	15	0.88

Fluid	Temperature		Kinematic Viscosity
	(°F)	(°C)	CentiStokes (cSt)
Acetone CH3COCH3	68	20	0.41
Alcohol - allyl	68 104	20 40	1.60 0.90 cp
Alcohol - butyl-n	68	20	3.64
Alcohol - ethyl (grain) C2H5OH	68 100	20 37.8	1.52 1.2
Alcohol - methyl (wood) CH3OH	59 32	15 0	0.74 1.04
Alcohol - propyl	68 122	20 50	2.8 1.4
Aluminum sulfate - 36% solution	68	20	1.41
Ammonia	0	-17.8	0.3
Aniline	68 50	20 10	4.37 6.4
Asphalt RC-0, MC-0, SC-0	77 100	25 37.8	159–324 60–108
Automatic crankcase oil SAE 10W	0	-17.8	1295–max
Automatic crankcase oil SAE 10W	0	-17.8	1295–2590
Automatic crankcase oil SAE 20W	0	-17.8	2590–10350
Automatic crankcase oil SAE 20	210	98.9	5.7–9.6
Automatic crankcase oil SAE 30	210	98.9	9.6–12.9
Automatic crankcase oil SAE 40	210	98.9	12.9–16.8
Automatic crankcase oil SAE 50	210	98.9	16.8–22.7
Automotive gear oil SAE 75W	210	98.9	4.2 min
Automotive gear oil SAE 80W	210	98.9	7.0 min
Automotive gear oil SAE 85W	210	98.9	11.0 min
Automotive gear oil SAE 90W	210	98.9	14–25
Automotive gear oil SAE 140	210	98.9	25–43
Automotive gear oil SAE150	210	98.9	43 – min
Beer	68	20	1.8
Benzene (Benzol) C6H6	32 68	0 20	1.0 0.74
Bone oil	130 212	54.4 100	47.5 11.6
Bromine	68	20	0.34

Fluid	Temperature		Kinematic Viscosity
	(°F)	(°C)	CentiStokes (cSt)
Butane-n	-50 30	-1.1	0.52 0.35
Butyric acid n	68 32	20 0	1.61 2.3 cp
Calcium chloride 5%	65	18.3	1.156
Calcium chloride 25%	60	15.6	4
Carbolic acid (phenol)	65 194	18.3 90	11.83 1.26 cp
Carbon tetrachloride CCl4	68 100	20 37.8	0.612 0.53
Carbon disulfide CS2	32 68	0 20	0.33 0.298
Castor oil	100 130	37.8 54.4	259–325 98–130
China wood oil	69 100	20.6 37.8	308.5 125.5
Chloroform	68 140	20 60	0.38 0.35
Coconut oil	100 130	37.8 54.4	29.8–31.6 14.7–15.7
Cod oil (fish oil)	100 130	37.8 54.4	32.1 19.4
Corn oil	130 212	54.4 100	28.7 8.6
Corn starch solution 22 Baume	70 100	21.1 37.8	32.1 27.5
Corn starch solution 24 Baume	70 100	21.1 37.8	129.8 95.2
Corn starch solution 25 Baume	70 100	21.1 37.8	303 173.2
Cotton seed oil	100 130	37.8 54.4	37.9 20.6
Crude oil 48o API	60 130	15.6 54.4	3.8 1.6
Crude oil 40o API	60 130	15.6 54.4	9.7 3.5
Crude oil 35.6o API	60 130	15.6 54.4	17.8 4.9
Crude oil 32.6o API	60 130	15.6 54.4	23.2 7.1
Decane-n	0 100	17.8 37.8	2.36 1.001
Diethyl glycol	70	21.1	32
Diethyl ether	68	20	0.32
Diesel fuel 2D	100 130	37.8 54.4	2–6 1.0–3.97
Diesel fuel 3D	100 130	37.8 54.4	6–11.75 3.97–6.78

Fluid	Temperature		Kinematic Viscosity
	(°F)	(°C)	CentiStokes (cSt)
Diesel fuel 4D	100 130	37.8 54.4	29.8 max 13.1 max
Diesel fuel 5D	122 160	50 71.1	86.6 max 35.2 max
Ethyl acetate CH3COOC2H3	59 68	15 20	0.4 0.49
Ethyl bromide C2H5Br	68	20	0.27
Ethylene bromide	68	20	0.787
Ethylene chloride	68	20	0.668
Ethylene glycol	70	21.1	17.8
Formic acid 10%	68	20	1.04
Formic acid 50%	68	20	1.2
Formic acid 80%	68	20	1.4
Formic acid concentrated	68 77	20 25	1.48 1.57cp
Freon -11	70	21.1	0.21
Freon -12	70	21.1	0.27
Freon -21	70	21.1	1.45
Furfurol	68 77	20 25	1.45 1.49cp
Fuel oil 1	70 100	21.1 37.8	2.39–4.28 -2.69
Fuel oil 2	70 100	21.1 37.8	3.0–7.4 2.11–4.28
Fuel oil 3	70 100	21.1 37.8	2.69–5.84 2.06–3.97
Fuel oil 5A	70 100	21.1 37.8	7.4–26.4 4.91–13.7
Fuel oil 5B	70 100	21.1 37.8	26.4– 13.6–67.1
Fuel oil 6	122 160	50 71.1	97.4–660 37.5–172
Gas oils	70 100	21.1 37.8	13.9 7.4
Gasoline a	60 100	15.6 37.8	0.88 0.71
Gasoline b	60 100	15.6 37.8	0.64
Gasoline c	60 100	15.6 37.8	0.46 0.40
Glycerin 100%	68.6 100	20.3 37.8	648 176
Glycerin 50% water	68 140	20 60	5.29 1.85 cp
Glucose	100 150	37.8 65.6	7.7M–22M 880–2420

Fluid	Temperature		Kinematic Viscosity
	(°F)	(°C)	CentiStokes (cSt)
Heptanes-n	0 100	-17.8 37.8	0.928 0.511
Hexane-n	0 100	-17.8 37.8	0.683 0.401
Honey	100	37.8	73.6
Ink, printers	100 130	37.8 54.4	550–2200 238–660
Insulating oil	70 100	21.1 37.8	24.1 max 11.75 max
Kerosene	68	20	2.71
Jet fuel	-30	-34.4	7.9
Lard	100 130	37.8 54.4	62.1 34.3
Lard oil	100 130	37.8 54.4	41–47.5 23.4–27.1
Linseed oil	100 130	37.8 54.4	30.5 18.94
Mercury	70 100	21.1 37.8	0.118 0.11
Methyl acetate	68 104	20 40	0.44 0.32 cp
Methyl iodide	68 104	20 40	0.213 0.42 cp
Menhaden oil	100 130	37.8 54.4	29.8 18.2
Milk	68	20	1.13
Molasses A, first	100 130	37.8 54.4	281–5070 151–1760
B, second	100 130	37.8 54.4	1410–13.2M 660–3.3M
C, blackstrap	100 130	37.8 54.4	2630–55M 1320–16.5M
Naphthalene	176 212	80 100	0.9 0.78 cp
Neatstool oil	100 130	37.8 54.4	49.7 27.5
Nitrobenzene	68	20	1.67
Nonane-n	0 100	-17.8 37.8	1.728 0.807
Octane-n	0 100	-17.8 37.8	1.266 0.645
Olive oil	100 130	37.8 54.4	43.2 24.1
Palms oil	100 130	37.8 54.4	47.8 26.4
Peanut oil	100 130	37.8 54.4	42 23.4

Fluid	Temperature		Kinematic Viscosity
	(°F)	(°C)	CentiStokes (cSt)
Pentane-n	0 80	17.8 26.7	0.508 0.342
Petrolatum	130 160	54.4 71.1	20.5 15
Petroleum ether	60	15.6	31(est)
Propionic acid	32 68	0 20	1.52 cp 1.13
Propylene glycol	70	21.1	52
Quenching oil (typical)			100–120
Rapeseed oil	100 130	37.8 54.4	54.1 31
Rosin oil	100 130	37.8 54.4	324.7 129.9
Rosin (wood)	100 200	37.8 93.3	216–11M 108–4400
Sesame seed oil	100 130	37.8 54.4	39.6 23
Sodium chloride 5%	68	20	1.097
Sodium chloride 25%	60	15.6	2.4
Sodium hydroxide (caustic soda) 20%	65	18.3	4
Sodium hydroxide (caustic soda) 30%	65	18.3	10
Sodium hydroxide (caustic soda) 40%	65	18.3	
Soya bean oil	100 130	37.8 54.4	35.4 19.64
Sperm oil	100 130	37.5 54.4	21–23 15.2
Sulphuric acid 100%	68 140	20 60	14.56 7.2 cp
Sulphuric acid 95%	68	20	14.5
Sulphuric acid 60%	68	20	4.4
Sulphuric acid 20%			
Tar, coke oven	70 100	21.1 37.8	600–1760 141–308
Tar, gas house	70 100	21.1 37.8	3300–66M 440–4400
Tar, pine	100 132	37.8 55.6	559 108.2
Toluene	68 140	20 60	0.68 0.38 cp
Triethylene glycol	70	21.1	40
Turpentine	100 130	37.8 54.4	86.5–95.2 39.9–44.3
Varnish, spar	68 100	20 37.8	313 143
Water, distilled	68	20	1.0038
Water, fresh	60 130	15.6 54.4	1.13 0.55
Water, sea			1.15
Whale oil	100 130	37.8 54.4	35–39.6 19.9–23.4
Xylene-o	68 104	20 40	0.93 0.623 cp

Information in this table courtesy of The Engineering ToolBox

Grease Lubrication

Many more bearings are lubricated with grease than oil because it is simple and easy to use. It also has the advantage because it can be retained in the bearing or housing and has good rigidity and consistency. When operating and environmental conditions allow, self-lubricated bearings can be used. These life-long lubrication bearings use seals to seal in factory lubrication and are generally used in low speed applications.

The National Lubricating Grease institute (NGLI), ASTM, and other organizations set standard classification, specifications, and testing methods for greases and other lubricants. This classification reflects a grease's ability to resist deformation and penetrate space between surfaces.

Table 24: *NLGI Grease Classification*

NLGI Number	Penetration Range[1]	Consistency[2]
000	445-475	Semifluid
00	400-430	Semifluid
0	355-385	Very Soft
1	310-340	Soft
2	265-295	Common Grease

NLGI Number	Penetration Range[1]	Consistency[2]
3	220-250	Semihard
4	175-205	Hard
5	130-160	Very Hard
6	85-115	Solid

NOTE:
1. From ASTM test methods, values represents 0.1 mm (0.0245 in) at 25°C (77°F).
2. Grease consistency is its resistance to deformation by an applied force and reflects it's ability to penetrate.

As can be seen in Table 25, using the proper lubricating grease is critical for safe bearing operation and depends on:

- Operating temperature.
- Expected bearing life.
- Required protection against external fluids and contamination.
- Desired noise level.

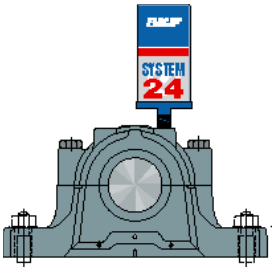


Table 25: *Grease Selection Based on Application*

APPLICATION		GREASE		
Speed[1] (nDm)	Load	Apparent Viscosity[2] (m Pa•s)	NLGI[3] Consistency	Thickener
Up to 600.000	Light/Medium	3.000	2	Lithium
Up to 600.000	High	4.000	2	Calcium/Lithium
Up to 900.000	Medium	3.000/4.000	2	Calcium/Barium/Lithium
Up to 900.000	Light	3.500/5.000	2	Calcium/Barium/Lithium

NOTE:
1. Bearing speed is expressed in terms of speed and bearing size. Refer to the section nDm for more information.
2. Definition found in glossary.
3. Refer to Table 24

In applications where the self-lubricating bearings are not used, periodic cleaning and replenishment is likely necessary to assure proper and consistent performance levels.

Table 26: *Ball Bearing Grease Relubrication Periodicity*

Bearing Bore	Bearing Speed (RPM)				
mm	5,000	3,600	1,750	1000	200
10	8,700	12,000	25,000	44,000	220,000
20	5,500	8,000	17,000	30,000	150,000
30	4,000	6,000	13,000	24,000	127,000
40	2,800	4,500	11,000	20,000	111,000
50		3,500	9,300	18,000	97,000
60		2,600	8,000	16,000	88,000
70			6,700	14,000	81,000
80			5,700	12,000	75,000
90			4,800	11,000	70,000
100			4,000	10,000	66,000

Improper type and/or application of grease can degrade bearing performance as listed in the troubleshooting section of this guide. For more information on greases, refer to Table 41 or contact Customer Service.

Grease Lubricating Methods

Two common methods of lubricating bearings with grease are packed and injected. Table 27 compares some common methods of oil delivery. [3]

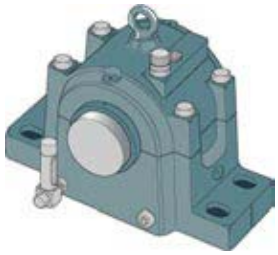


Table 27: *Common Methods of Grease Lubrication for Bearings*

Method	Description	Complexity	Effects of		
			Contaminants	Heat	Speed
Packed	Usually referred to as self-lubricated, these bearings are factory filled with grease that should outlast the life of the bearing.	Simple Maintenance free for the life of the bearing.	Bearing seals hold grease in and contaminants out.	Bearing and lubricant operate at the same temperature. This means grease must be able to maintain full-film during operation.	Without a means of dissipating heat, speeds must be low.
Injected	The bearing housing must include a means of injecting grease into the bearing on a periodic basis.	Moderate Periodic injection of grease can be accomplished manually or automatically.	Same as packed, but heated grease or contaminants may pass around seals.		Speed will increase heat and can effect the functionality of seals.

Oil Lubrication

As learned from the previous discussions on lubricants and lubrication, requirements very widely among bearing applications. Because of the fluidity and low viscosity (Table 23) of oil, it has an advantage over grease because it can be more easily pumped to several locations from a single source. Because oil is generally passed over a bearing before it is returned to the pumping source, it can carry heat away from the bearing. This is primarily why oil, as a spray or mist, is preferred in high speed applications.

Improper type and/or application of lubricant can degrade bearing performance as listed in the troubleshooting section of this guide. For more information on oil lubricants, refer to Table 41 or contact Customer Service.

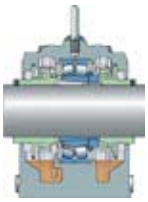
Oil Lubricating Methods

Several methods are used to oil to and into bearings. Table 28 compares some common methods of oil delivery. [3]

Figure 17: *Sample Methods of Oil Lubricating Systems*

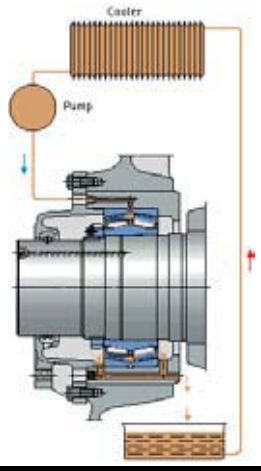
Oil Bath

Oil Pick-up Ring



Oil Jet

Circulating Pump



Spot or Oil-Air

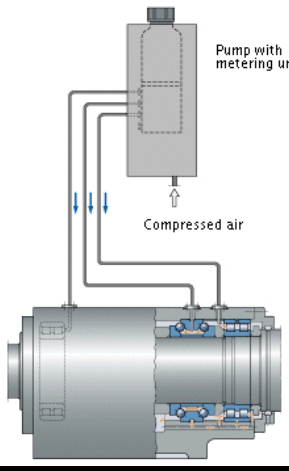


Table 28: *Common Methods of Oil Delivery for Bearings*

Oil Lub Method	Description	Complexity	Effects of		
			Contaminants	Heat	Speed
Bath	Oil is picked up by rolling elements that pass through an oil reservoir. The oil then flows over bearing components, back to the bath.	Simple No hoses or pumps.	Depends on housing and/or seals.	Thins oil to point where pick-up capability is reduced.	High speeds can lower the oil level below moving parts and generate heat.
Pick-up ring	Similar to bath method, but a ring, designed to carry oil, delivers oil to bearing components as it rotates with the shaft.	Simple	Depends on housing and/or seals.	Scooping effect of ring is not effected by heat.	Better than bath method.
Circulating	A pump is used to deliver oil to bearing components.	Moderate	A filter can be used to capture harmful particles.	Heat is carried away with oil flow. Oil can be cooled.	Depends on lubricant and ability to manage heat.
Jet	Similar to circulating method, but jet action sprays oil directly onto rolling elements, then flows downward to exit ports.	Fairly complex Adequate pressure and jet velocity is important.	Must be filtered to avoid clogging of jet that also washes away contaminants.	Increased flow of cooled oil easily carries away heat.	Works very well at high speeds.
Spot (Oil-Air)	Air pressure is used to deliver metered quantities of oil to bearing surfaces. This is the most effective method of lubrication.	Complex Combines air and oil to lubricate multiple bearings through hose/ nozzle system.	Along with filtration, the compressed air creates a clean positive atmosphere in the system.	A fresh air flow serves to cool bearing components.	Excellent heat control allows high speed operation with the proper lubricant.
Mist	Similar to the jet method, but oil is conveyed in the form of a mist that can cover a larger area. Not commonly used.	Complex Environmentally safe lubricants should be used.	Similar to Jet, with a fraction of the flow.	Similar to Jet, but a light mist is less effective.	Speeds are not as high as Jet or Spot.

Oil Change

The frequency with which it is necessary to change the oil depends mainly on the operating conditions and the quantity of oil.

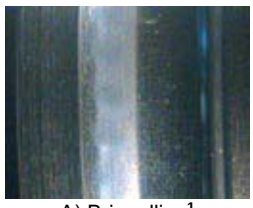
With oil bath lubrication it is generally sufficient to change the oil once a year, provided the operating temperature does not exceed 50 °C and there is little risk of contamination. Higher temperatures call for more frequent oil changes, e.g. for operating temperatures around 100 °C, the oil should be changed every three months. Frequent oil changes are also needed if other operating conditions are arduous.

With circulating oil lubrication, the period between two oil changes is also determined by how frequently the total oil quantity is circulated and whether or not the oil is cooled. It is generally only possible to determine a suitable interval by test runs and by regular inspection of the condition of the oil to see that it is not contaminated and is not excessively oxidized. The same applies for oil jet lubrication. With oil spot lubrication the oil only passes through the bearing once and is not recirculated.

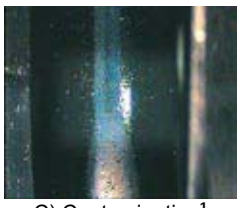
BEARING TROUBLESHOOTING

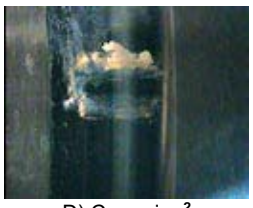
The published life of a bearing is based on the fatigue failure of rings or rolling elements. The expected life of a bearing can be decreased by many internal and external influences that exist in the mechanics and the surrounding environment. Although many bearings are self-lubricating and mostly maintenance free, unpredictable conditions can negatively effect bearing performance. The following images show some common effects of bearing damage. [3][6]

Figure 18: *Common Effects of Bearing Damage*

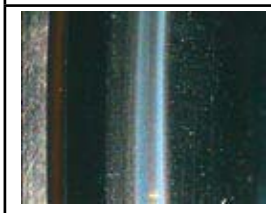

A) Brinnelling[1]


B) False Brinnelling[2]


C) Contamination[1]

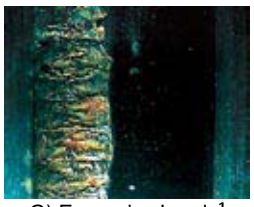

D) Corrosion[2]

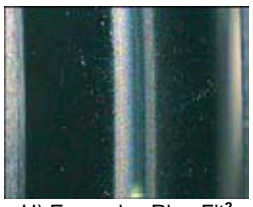

E) Electrical Arc Damage[1]
(Fluting or Washboarding Pattern)




J) Misalignment[2] (Same bearing raceway, two locations)


F) Excessive Radial Clearance[3]

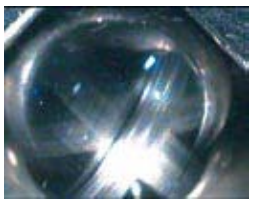

G) Excessive Loads[1]


H) Excessive Ring Fit[2]


I) Fatigue[1]


K) Lubrication Issues[1]


L) Overheating[2] (>200°C)


M) Reverse Loading

NOTE: Letter codes are referenced from Table 29.

NOTE:
1 Photo taken from inner ring raceway, may also appear in outer raceway.
2 Photo taken from outer ring raceway, may also appear in inner raceway.
3 Photo taken from outside surface of outer ring.

Should bearing problems exist, the next two tables can be used to determine the most likely cause, based on the effects, and a probable solution. The two tables are linked by a common set of numbered codes. [3][6]

Table 29: *Probable Causes for Bearing Failure*

Bearing Damage Effect									Probable Cause		
Frequent replacement	Loose bearing on shaft	Noise	Overheating	Performance unsatisfactory	Shaft is hard to turn	Vibration[1]	Secondary	Image (See Figure 18)	Primary	Secondary	Trbl Code[2] (see Table 30)
■		■		■		■		E K	Electrical current flowing through bearing	Asymmetry in the motor's magnetic circuit; unshielded power cables; and fast-switching variable frequency drives (VFDs)	53
		■		■		■	Fretting corrosion on outer ring outside surface	F	Excessive bearing clearance		43
							False brinnelling	B G M	Excessive load	Static bearing exposed to vibration	51
■		■	■	■	■			G H L	Oversized shaft		47

Bearing Damage Effect									Probable Cause		
Frequent replacement	Loose bearing on shaft	Noise	Overheating	Performance unsatisfactory	Shaft is hard to turn	Vibration[1]	Secondary	Image (See Figure 18)	Primary	Secondary	Trbl Code[2] (see Table 30)
		■						A	Other components	Components not part of bearing application	41
■		■	■	■	■			G H J L	Preloaded bearing	Cross location (similar to cross thread)	15
■		■	■	■	■			G J L		Two locating bearings on one shaft	16
		■		■		■		A	Unbalanced load		44
■		■	■	■	■		Bearing fit	H L	Bearing clearance	Insufficient (Bearing has inadequate internal clearance for conditions where external heat is conducted through the shaft. This causes the inner ring to expand excessively.)	4
■	■	■		■		■			Too loose	Bearing bore too large	17
■	■	■		■		■				Adaptor sleeve not tight or excessively tight	18
■		■	■	■	■			G H I L	Too tight		19
■		■		■	■	■	Contaminants	C	Abrasive debris	Sand, carbon, etc. (can be introduced before and during installation)	5
■		■	■		■			L	Flinger out of position	Rubbing against cover	38
■		■		■	■	■		D	Corrosive liquids	Water, acids, paint, etc.	6
■		■		■	■	■		C	Objects in bearing	Chips, dirt or other objects in housing	10
■		■	■	■		■	Excessive peening of non-ferrous housing	F L	Enlarged housing bore		50
■		■		■	■	■	Housing problem		Bearing fillet too large relative to housing fillet	Inadequate support	30
■		■	■	■		■		F L	Oversized housing bore		49
■		■		■	■	■			Shoulder too small	Inadequate shoulder support	27
■		■		■		■			Shoulder too large	Distorted bearing seals	28
■				■				G I	Tapered housing bore	Skewed load concentration	24
■		■	■	■	■			G H I L	Undersized housing bore		48
		■	■	■	■		Locking Washer	C L	Bent prongs	Rubbing against bearing	37
			■		■		Lubrication problems – discolored blue or brown tracking bands on rings and balls is a good sign of lubrication problems	K L	Excessive	Housing is too full of oil or grease	3
■		■	■		■			K L	Inadequate	Incorrect lubricant being applied	1
■		■	■		■			K L	Insufficient (low oil or grease)	Damaged or worn seals	2
■			■					K L	Oil gauge breather hole clogged	Incorrect oil level	32
■			■					K L	Oil level cups consistent		35
■			■					K L		Incorrect location	36

Bearing Damage Effect									Probable Cause		
Frequent replacement	Loose bearing on shaft	Noise	Overheating	Performance unsatisfactory	Shaft is hard to turn	Vibration[1]	Secondary	Image (See Figure 18)	Primary	Secondary	Trbl Code[2] (see Table 30)
■							Oil leakage		Air velocity over bearing causing pressure differentials	Air velocity too high	11
■									Split plummer (pillow) block	Uneven surfaces	20
			■					L	Return holes plugged		14
■		■	■	■		■	Outer ring spins	L	Unbalanced load		21
■		■	■	■				F L	Oversized housing bore		49
■		■	■	■	■	■	Pinched bearing in housing	G I J L	Bore out of round		7
■		■	■	■	■	■		J I L	Bent housing	Supporting surface uneven	39
■		■	■	■	■	■		G I J L	Warped housing		8
■		■		■		■	Rolling element problem (bearing or roller)	A I	Dented roller	Blows to bearing	40
		■							Discolored	Blow torch was used to remove bearing	46
		■			■			C I	Flattened surface	Skidding	22
		■			■			C M	Reverse loading (off-loading)	Angular contact bearing mounted backwards	52
			■				Seal problem	L	Distorted seals	Too tight	12
■		■	■		■			C L	Labrinth seals rubbing	Insufficient clearance	31
■		■	■					C L	Lubricant leakage	Worn seal	42
■		■	■						Dirt in bearing		
		■	■		■			C L	Misaligned seals	Rubbing against stationary parts	13
■		■		■	■	■	Shaft problem	H	Bearing fillet too large relative to shaft fillet	Bearing not properly seated	29
■		■		■	■	■				Bending of shaft	
■			■	■	■	■		H L	Misalignment	Angular	34
■			■	■	■	■		H L		Linear	33
■			■	■		■		H I	Tapered shaft seating	Skewed load concentration	23
■		■		■	■	■			Shoulder too small	Inadequate shoulder support	25
■		■	■		■			L	Shoulder too large	Rubbing against bearing seals	26
■				■	■		Shaft turns with difficulty	H		Shaft or housing shoulders are out of square with bearing seating	45
■		■	■	■	■	■	Shim problem	H I L	Uneven	Distorted housing bore – possible cracking of base	9

NOTE: [1] For information on controlling vibration, refer to the Leveling Devices and Vibration Control Resource Guide.
[2] For ideas on how to resolve an issue, look up matching code in Table 30.

Table 30: *Troubleshooting Solutions*

Effect							TrbI Code[1] (See Table 29)	Reason for Bearing Condition	Probable Solution
Frequent replacement	Loose bearing on shaft	Noise	Overheating	Performance unsatisfactory	Shaft is hard to turn	Vibration[1]			
■		■	■		■		1	Operating conditions causing breakdown of grease or oil. This happens because the lubricant film has been unable to maintain sufficient thickness to prevent surface to surface contact. Lubrication failure could mean that it is wrong for the application or that the supply is marginal and hence a full film can not develop.	Contact Customer Service to determine proper type of lubricant. Check miscibility if grease or oil has been changed from one type to another.
■		■	■		■		2	Low oil level. Lubricant is being lost through the seal. Insufficient grease in the housing.	Oil level should be just below the centre of the lowest rolling element in the bearing. Fill housing 1/3 to 1/2 with grease.
							3	Housing is fully packed with grease, or the oil level is too high. This causes excessive lubricant churning, high operating temperature or oil leakage.	Purge grease until the housing is 1/2 filled with grease. For oil lubricated bearings, reduce the oil level to just below the centre of the lowest rolling element.
■		■	■	■	■		4	Bearing has inadequate internal clearance for conditions where external heat is conducted through the shaft. This causes the inner ring to expand excessively.	Check whether overheated bearing had clearance according to original design specification. If so, then change to bearing with increased radial clearance, e.g. Normal to C3 or C3 to C4. If not, order to specification. Replace as needed.
■		■		■	■	■	5	Dirt, sand, carbon, or other contaminants previously existed or are entering the bearing housing. A dirty environment can introduce debris during storage or assembly.	Clean the bearing housing. Replace worn seals or improve the seal design to obtain adequate bearing protection. Check for contaminants in lubricant.
■		■		■	■	■	6	Water, acids, paints or other corrosives are entering the bearing housing or were previously introduced.	Install a protective shield and/or flinger to guard against foreign matter. Improve seals.
■		■	■	■	■	■	7	Housing bore is out-of-round. Housing is warped or distorted. Supporting surface uneven. Housing bore is undersized.	Check and scrape the housing bore to relieve pinching of the bearing. If necessary turn the housing bore to the correct dimension. Ensure that the supporting surface is flat and that the shims cover the entire area of the housing base. Housing bore is undersized if non-locating bearing is changed from separable to non-separable bearing, e.g. from cylindrical roller bearing to deep groove ball bearing.
■		■	■	■	■	■	8		
■		■	■	■	■	■	9		
■		■	■	■	■	■	39		
■		■	■	■	■		48		
■		■		■	■	■	10	Chips, dirt etc. were not removed from housing before assembling the bearing unit. Fretting corrosion can internally generate contaminants.	Carefully clean, and apply fresh lubricant. Look for sign of bearing damage, such as those shown in Figure 18.
■							11	Air flowing over the bearing is causing an oil leak. (Example: Forced draft fan with air inlet over the bearing.)	Install baffles to divert the air flow. Avoid pressure difference over the bearing. Use grease lubrication if possible.
			■		■		12	Contact seals are dried out or have excessive spring tension.	Replace contact seals with seals having correct spring tension. Lubricate seals.
			■		■		13	Rotating seals or flingers are rubbing against stationary parts.	Check the running clearance of the rotating seal or flinger to eliminate rubbing. Correct the alignment.
■			■		■		31		
■			■		■		38		

Effect							Trbl Code[1] (See Table 29)	Reason for Bearing Condition	Probable Solution
Frequent replacement	Loose bearing on shaft	Noise	Overheating	Performance unsatisfactory	Shaft is hard to turn	Vibration[1]			
			■				14	Oil return holes are blocked. Pumping action of the seals causes oil leakage.	Clear the holes. Drain used oil and refill to the proper level with fresh lubricant
■		■	■	■	■		15	Cross location (similar to cross thread)	Insert shim between housing and cover flange to relieve axial preloading of bearing.
■		■	■	■	■		16	Two locating bearings on one shaft. Insufficient clearance in bearing caused by excessive shaft expansion.	Move the covers in one of the housings outwards. Use shims to obtain adequate clearance between the housing and the outer ring. Apply axial spring load on the outer ring, if possible, to reduce axial play of the shaft.
■							17	Shaft diameter is too small. Adapter is not sufficiently tightened.	Metallise and regrind the shaft to obtain the proper fit. Retighten the adapter for a firm grip on shaft.
■							18		
■		■	■	■	■		19	Adapter sleeve is tightened excessively.	Loosen the lock nut and sleeve assembly. Retighten it sufficiently to clamp the sleeve on to the shaft, but be sure the bearing turns freely.
■							20	Oil is leaking at the housing split. Excessive loss of lubricant.	A thin layer of gasket cement will stop minor leaks. Do not use shims. Replace the housing if necessary.
■							21	Unbalanced load.	Rebalance the machine. Replace the housing with one having the proper bore.
■							49	Housing bore is too large.	
■							22	Flat spot on rolling element due to skidding. (Caused by fast starts). Any wearing of internal components can introduce contaminants in bearing.	Visually check the rolling elements and replace the bearing if a rolling element has a flat spot. Make sure that the requisite minimum load is applied to the bearing.
■							23	Unequal load distribution on the bearing due to out-of-form of shaft seating or housing bore.	Rework[3] the shaft and/or housing seating to obtain the proper form and fit. The application may require a new shaft or housing.
■							24		
■							25	Shaft is bending due to incorrect shoulder diameter.	Remachine[3] the shaft fillet to relieve stress. The application may require a shoulder collar. Check that abutment dimension is in accordance with manufacturer's recommendations.
■							26	Shaft shoulder is rubbing against bearing seals. Any wearing of internal components can introduce contaminants in bearing.	Remachine[3] the shaft shoulder to clear the seals. Check that shoulder diameter is in accordance with manufacturer's recommendations.
■							27	Inadequate support in the housing is causing the outer ring to distort.	Remachine[3] the housing fillet to relieve stress. Check that abutment dimension is in accordance with manufacturer's recommendations. The application may require a shoulder collar.
■							28	Distorted bearing seals.	Remachine[3] the housing shoulder to clear the seals.
■							29	Shaft and inner ring are distorted.	Remachine[3] shaft fillet to obtain the proper support.
■							30	Housing and outer ring are distorted.	Remachine[3] the housing fillet to obtain the proper support.
								For 31, see #13	
■			■				32	No lubricant in bearing due to incorrect oil level.	Clear out the clogged oil hole to vent the oil gauge.

Effect							Trbl Code[1] (See Table 29)	Reason for Bearing Condition	Probable Solution
Frequent replacement	Loose bearing on shaft	Noise	Overheating	Performance unsatisfactory	Shaft is hard to turn	Vibration[1]			
■			■	■	■		33	Incorrect linear or angular alignment of two or more coupled shafts with two or more bearings.	Correct alignment by shimming the housings. Ensure that the shafts are coupled in a straight line, especially when three or more bearings operate on one shaft. Be sure to use full support shims.
■			■	■	■		34		
■			■			■	35	Constant oil level cup is mounted too high or too low.	The static oil level must not be higher than the centre of the lowest rolling element. Replace the constant level oiler with a sight gauge.
■			■				36	The cup is located opposite to the bearing's direction of rotation.	Locate cup with bottom of bearing and shaft rotating toward the cup.
			■	■	■		37	Washer prong is rubbing against the bearing.	Remove the locking washer. Straighten the prong or replace with a new washer.
								For 38, see #13 & #31; for 39, see #7	
■		■		■		■	40	Incorrect mounting method. Hammer blows to bearing.	Replace the bearing with a new one. Never hammer any part of a bearing when mounting. Always use a mounting dolly or sleeve.
		■					41	Moving components in the machine are interfering with bearing operation.	Carefully check every moving component in the machine. Clear whatever is interfering.
■		■	■				42	Contact seals are excessively worn, causing lubricant loss or permitting dirt to enter the bearing.	Replace seals after thoroughly flushing bearing and refilling with fresh lubricant.
		■		■		■	43	Excessive clearance in the bearing is causing vibration.	Use a bearing with recommended internal clearance. Apply spring load to the outer ring of the non-locating bearing to eliminate axial and radial play.
		■		■		■	44	Equipment is vibrating.	Check the balance of the rotating parts. Rebalance the equipment.
■				■	■		45	Shaft or housing shoulders or lock nut face out-of-square with the bearing seat.	Remachine[3] parts to obtain squareness.
		■					46	Distortion of the shaft and other bearing arrangement components, probably due to heat.	Use a torch to remove a bearing only under extreme circumstances, use a proper dismounting tool. Avoid high heat concentration at any one point to prevent distortion. Replace discolored bearings.
■		■	■	■	■		47	Bearing seating diameter is oversized, causing excessive inner ring expansion. This reduces bearing clearance.	Grind shaft to get a proper fit between the shaft and the bearing inner ring. If regrinding is not possible change to bearing with larger radial clearance.
								For 48, see #7; for 49, see #21	
■		■	■	■		■	50	"Pounding out" or hammering out of housing bore due to too soft metal. The resulting enlarged bore causes the outer ring to spin in the housing.	Rebore[3] the housing and press a steel bushing in the bore. Machine the bushing bore to the correct size.
		■		■			51	Bearing is exposed to vibration while the machine is idle. **NOTE:** Lubrication is ineffective in a static bearing.	Carefully examine the bearing for wear spots or indentations corresponding to the spacing of the rolling elements. For standby equipment ball bearings are better suited than roller bearings to withstand vibration. Locking shaft motion while idle can help.

Effect							Trbl Code[1] (See Table 29)	Reason for Bearing Condition	Probable Solution
Frequent replacement	Loose bearing on shaft	Noise	Overheating	Performance unsatisfactory	Shaft is hard to turn	Vibration[1]			
		■		■		■	52	Angular ball bearings are designed to support axial loads that act in one direction only. If a reverse load is applied the contact area between the ball and the outer ring moves towards the non-thrust side which has a lower shoulder height. The result is that the ball/raceway contact ellipse becomes truncated resulting in high contact stresses and rapid failure.	Visually check to ensure bearing is mounted in the correct direction. Visually check ball elements and raceway shoulders. If damage is minimal, remove and correctly mount bearing. If effects persist after properly mounting bearing, replace the bearing.
■							53	When an electrical current passes through a bearing, it tends to arc between non-contacting balls and raceways leaving visual patterns that range from random pitting to fluted patterns.	Consider bearing with hybrid, non-conductive, ball bearings. Re-route the current to by-pass the bearing.

NOTE:
1. For information on controlling vibration, refer to the Leveling Devices and Vibration Control Resource Guide.
2. For troubleshooting effect and probable causes, refer to Table 29. Match code with codes in this table for most like solutions.
3. Metal working resources are available at Reid Entities TQM machine shop. Contact Customer service for more information.

Selecting the Correct Bearing

With so many varieties, attributes, and applications, it can sometimes be difficult to select the correct bearing. When replacing a bearing, bearing designations standards can be vague and limited. For this reason, manufacturers append prefixes and suffixes on ANSI/ABMA and/or ISO bearing designations to further identify many aspects of the existing bearing. As stated previously, normally bearing information can be found on the widest edge of the inner ring. If not found, measure bearing dimensions and contact Customer Service.

The tables in this section compares various bearing types and can help when selecting and replacing bearings.

Table 31: *Selection Chart for Roller Bearings*

Bearing Type	Attributes	Coefficient of Friction (μ) {6}	Alignment Errors During Operation	Alignment Errors, Initial	Axial Displacement	Axial Load Only	Combined Load	High Running Accuracy	High Speed	High Stiffness	Location Gearing Installation	Low Friction	Moment Load	Non-Location Gearing Installation	Quiet Running	Radial Load Only
Ball	Single-row	0.0015	P	P	–	S	S	E	E	S	G	E	P	S	E	S
	Self-aligning	0.0010	E	G	–	P	P	G	G	P	S	G	–	S	G	S
	Angular Contact		P	P	–	S	G	E	G	S	G	G	P	–	G	S
	Angular Contact		–	–	–	S	G	G	S	G	G	S	S	S	S	G
	Four Point Contact		–	–	–	S	S	S	G	S	G	S	S	P	S	P
Cylindrical Roller	N, NU	0.0011	P	P	E	–	–	G	E	G	–	G	–	E	G	G
	NJ, NUP		P	P	S	S	S	G	E	G	S	G	–	S	S	G
	Double-row		–	–	E	–	–	E	E	E	–	G	S	E	G	E
	Full Compliment		P	P	S	S	P	S	P	E	S	P	–	S	P	E
	Full, Double-row		–	–	S	S	P	S	P	E	S	P	S	S	P	E
Needle Roller	Needle		–	–	E	–	–	S	S	G	–	P	–	E	S	G
Spherical Roller	Spherical	0.0018	E	G	–	S	E	S	S	G	G	S	–	S	S	E
Taper	Roller	0.0018	P	P	–	G	E	G	S	G	G	S	–	–	S	G
	Roller, Face to Face		P	P	–	G	E	S	S	E	E	S	P	S	S	E
Thrust	Ball	0.0013	–	–	–	S	–	G	S	S	S	S	–	–	P	–
	Ball with Spherical Housing Washer		–	-	–	S	–	S	S	S	S	S	–	–	P	–
	Cylinder Roller		–	–	–	G	–	G	P	G	S	P	–	–	P	–
	Needle Roller		–	–	–	G	–	S	P	G	S	P	–	–	P	–
	Spherical Roller		E	G	–	E	S	S	S	G	G	S	–	–	P	–

E = Excellent G = Good S = Satisfactory P=Poor – = Not Related

PLAIN BEARINGS

Plain bearings include those with non-rolling elements. They are typically made of materials which take advantage of shape, surface preparation, material properties, and lubrication. Plain bearings have been used for many years to control friction and heat in mechanical systems.

When selecting plain bearings for replacement shape, size dimensions and material are most important. In some cases, an exact match may not be available, but purchasing a bearing of a size and shape that can be machined, may be the only solution.

Use the next two tables to select the best plain bearing for your application or replacement part. Specifications for plain bearings include P, V, and PV values which are explained in the PV Calculation section of this guide.

Table 32: *Plain Bearing Types*

Plain Bearing Types	Pros	Cons
 Cylindrical Bushings	High tolerances are ideal for use in dies and molds.	
	• Available with, or without, graphite plugs.	• Bushings without graphite plugs, require lubrication.
 Metric Dry	Steel backed, sintered bronze PTFE and lead lined bearings. These bearings are used in dry or semi-lubricated environments with temperatures ranging from -319°F to 512°F (-195°C to 267°C).	
	• Save space over conventional bearings. • Maintenance free. • Provide superior shock and impact load resistance. • Maintains a low coefficient of friction, without lubrication, at high load and low speed.	
 Wearstrips	Provide a very effective and economical means of controlling and guiding linear motion, especially in applications where large loads are present such as dies, molds and heavy machinery.	
	• Semi-finished and are intended to be cut to size and finished by customer. • Made of solid aluminum bronze and are 40" in length with longer length available upon request.	• Drill mounting holes either between or through graphite plugs. When going through a plug, first break out graphite with a center punch and you'll have a prespotted hole.

Plain Bearing Types	Pros	Cons
Sleeve Bearing	Also referred to as bushing or journal bearings, are used to constrain, guide and reduce friction in rotary or linear applications. Today's manufactures produce a wide range of sizes and material properties that meet industry demands. They can be found in food processing machinery, home appliances, office machines, agricultural, medical, packing and automotive equipment, to name a few.	
 Cast Bronze	Cast bronze bearings are machined from continuous cast C93200 (SAE660) bronze for superior quality and performance. Commonly used in all kinds of agricultural and industrial machinery and equipment.	
	• The continuous casting process assures a uniform bronze structure throughout the bearing, free from porosity and hard particle inclusions commonly found in other cast processes. • These solid bearings are ideal in heavy load applications. • Max P = 4,000, Max V = 750 with a Max PV = 75,000.	• May need a lubricant.
 Oil Impregnated	"Oilite type" sintered bronze stock bearings are vacuum impregnated with SAE30 oil that provides lubricant which is metered from the bearing to the shaft during rotation. They are ideal for all applications where repeat lubrication is difficult, including all agricultural and industrial machinery and equipment.	
	• Self-lubricating. • Conform to ASTM chemical and physical properties. • Include all ASTM standard sizes to all ASTM recommended dimensions and tolerances. • Temperature ranges of 10°F to 220°F (-12°C to 104°C). • Max P = 2,000, Max V=1,200 and Max PV = 50,000.	
 Graphite-Metal	These bearings are perfect for use in ovens, dryers and heat treating furnaces; ideal in dry, wet (even submerged) and corrosive environments. Solid graphite with molten copper impregnated into the pores are suitable for hard shafts.	
	• Self-lubricating. • Temperature ranges of -450°F to 750°F (-268°C to 399°C). • Max PV = 46,000.	
 Graphite Plugged	Graphite plugged bearings are self-lubricating and operate at higher temperatures than standard self-lubricating bearings.	
	• Can operate in temperatures up to 250°F (121°C), and 750° (399°C) bearings are available. • Lubricate on both sides.	
	• Maintenance-free. • Can be re-machined to size and shape. • Work well in hazardous environments.	

Plain Bearing Attributes

Because plain bearings are metal shapes, they can be re-shaped as needed by the OEM or the customer. Manufacturers stock many popular shapes listed in Table 33.

Table 33: *Plain Bearing Attributes*

Plain Bearing Attributes	Pros	Cons
 Flange Mount	Some bearings and bushing can have a flange at one, or both (special order), ends of the bearing.	
	• Depending on application and mounting, provides bearing action in radial and axial directions. • Allows mounting support on one end of bearing or bushing.	
 Graphited Plugged	Plain bearings or bar stock can be machined, grooved, graphited, drilled or re-machined in many ways to handle a variety of needs. Six most popular graphited styles are shown.	
	• Unless otherwise specified, the width and depth of grooves will be proportional to the wall thickness and size of bearing, contained within the bearing. • Special designs are also available.	• Depth of groove is limited by wall thickness. • Graphited bearing ID must be from 0.001 to 0.002 in greater than normal.
	 Style 5G  Style 7A  Style 9  Style 10  Style SKR	
 Oil Grooved Straight	Plain bearings or bar stock can be machined, grooved, drilled or re-machined in many ways to handle a variety of needs. For grooved bearings, oil enters bearing from the shaft and collects in the grooves. Popular grooves are shown below.	
	• Unless otherwise specified, the width and depth of oil grooves will be proportional to the wall thickness and size of bearing, contained within the bearing. • Special designs are also available.	• Depth of groove is limited by wall thickness.
 Circular	 Style 1  Style 2  Style 3  Style 4  Style 5	

ROLLER BEARING STYLES

The difference between roller bearings and plain bearings is that, roller bearings have rolling elements. Bearing types are generally classified based on the type of element employed: ball, cylindrical roller, tapered roller, needle, or self-aligning. Each type, and more, are listed and compared in Table 34.

Table 34: *Roller Bearing Types*

Roller Bearing Types	Pros	Cons
 Angular	Designed to support radial and thrust loads. Widely used in high speed and temperature applications. May include hybrid bearings with nitride balls and steel races.	
 Single-Row	Designed for combination loads absorbed at a specified angle between the inner to the outer ring.	
	• Can manage both radial and axial loads. • Can be mounted in pairs (duplex) back-to-back, face-to-face, or tandem.	• Usually used in bearing sets or at opposite ends of a shaft.
 Double-Row	Functions similar to two face-to-face single-row angular-contact bearings.	
	• Rolling element fit is not dependent on housing design for internal rigidity, as with duplex bearing sets. • Usually preloaded for maximum resistance to deflection from either direction.	
	• Typical angles are 15°, 30°, and 40°. • Radial and thrust limits depend on race angle for inner, outer or both rings.	• If placed backwards, may come apart during operation.
 Ball	The most common type of bearing used to manage light radial loads. The load is transmitted from the outer race to the ball, and from the ball to the inner race.	
 Single-Row	Uses a single row of balls, usually separated by a cage.	
	• Very smooth operation. • Deep groove type offers greater thrust load support.	• Usually found in applications where loads are relatively small.
 Double-Row	Uses two matching rows of balls separated by a bearing race and a cage or separator.	
	• Provides for heavy radial and light thrust loads at comparable OD.	• Can be 60 to 80 percent wider than single-row bearing.
	• Can handle both radial (primary) and thrust loads. • Very smooth operation. • Seals and other attributes can be applied.	• Ball contact to inner and outer race is at a single point to each. • If overloaded, balls can deform or squish, ruining the bearing. • Not self-aligning, must be accurately mounted.
 Cylindrical Roller	Used in applications like conveyer belt rollers, where they must hold heavy radial loads. Linear contact spreads the load out over a larger area, allowing the bearing to handle much greater loads than a ball bearing.	
	• Able to handle large radial loads. • Contact between the inner and outer race is not a point, but a line.	• Cannot handle much thrust loading.

Roller Bearing Types	Pros	Cons
 Needle	Similar to cylindrical roller bearings, needle rolling elements are smaller and longer. They also have some clear advantages.	
	• Thin and lightweight with high load carrying capacity. • Inner ring is optional for some applications. • Two or more rows allow support over long lengths.	• Cannot handle much thrust loading.
 Polymer Ball	Polymer ball bearings can be made from a variety of materials and material combinations. The materials selected depend on the application.	
	• Corrosion and chemical resistant. • Have a low coefficient of friction and are highly resistant to wear and fatigue. • Self-lubricating bearings can run dry and require no relubricant. • Non-conductive. • 80% lighter than steel.	• Loads and maximum speeds are much lower than that of conventional all-steel bearings.
 Self-Aligning	These bearings are designed to self-align under radial loads. They can be either ball or spherical roller elements, single or double row; depending on load requirements.	
	• Can self-align with ±4° of axial axis.	• Thrust loads of 10 percent of radial load or greater can cause early failure.
 Spherical	An excellent choice for applications where the shaft or mounting surface bends or moves.	
	• Self-aligning and very robust. • Can carry heavy loads.	
 Tapered Roller	Commonly used in hubs. For car hubs, they are usually mounted in pairs facing opposite directions so that they can handle thrust in both directions.  Cone  Cup  Set	
	• Can support large radial and large thrust loads. • Components can be ordered separately or as a set.	• Usually larger than ball bearings.

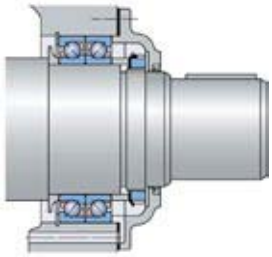
Roller Bearing Types	Pros	Cons
 Thrust	Used to control friction under axial loads, thrust bearings are available in a variety of designs, including self-aligning.	
 Ball	Used for low-speed applications like barstools and Lazy Susan turntables.	
	• Very smooth operation. • Can be operated at high speeds with low friction and heat. • More tolerance to misalignment than roller bearings.	• Cannot handle much radial load.
 Nylon	A unique design with a molded nylon retainer.	
	• Provides superior performance and economical characteristics. • Quiet operation. • Retainer is lightweight, naturally lubricated, and corrosion resistant.	• Low tolerance to heat. • Should be used for relatively slow speeds.
 Roller	Often found in gearsets like car transmissions between gears, and between the housing and the rotating shafts.	
	• Can support large thrust loads. • Tapered rollers also available.	• Can be noisy.
	• Reduce friction induced by axial loads.	• Cannot handle much radial load.

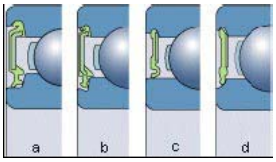
Roller bearing Attributes

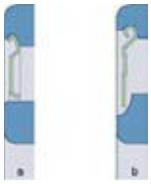
Many attributes are available to enhance bearing performance and alter application requirements. These attributes can seal in lubricants and seal out contaminants, protect elements, change mounting and increase service life.

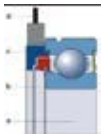
Table 35: *Roller Bearing Attributes*

Bearing Attributes	Pros	Cons
 Balls	Used by leading bearing manufacturers, of precision ball bearings.	
	• Available in ANSI 52100 chrome, ANSI 440 stainless steel, tungsten carbide and ceramic materials. • Inch and metric sizes available. • Precise spherical and tolerance accuracy.	
 Extended	Many bearings are available with an extended inner ring.	
	• Extension can be on one or both sides. • Can include set screw(s) for secure mounting on a shaft.	• Increased bearing size.
 Filling Slot	This feature includes a filling slot in both inner an outer rings that, when aligned, allow bearings or rollers to be inserted or removed. Refer to Figure 7.	
	• Has a higher radial load capacity that can be changed by adding or removing balls or rollers. • Cage is optional.	• Small axial load capacity. • Not recommended for axial loads greater than 60% or radial load. • Operate at slower speeds than bearings without filling slot.







Bearing Attributes	Pros	Cons
 Flanged	Depending on the application, there are many ways to take advantage of the flange on a flanged bearing.	
	• Used for secure mounting on one side of a shaft. • Can be a locating point for mounting or when used as a cam follower.	
 Locknut	To get a more secure position on a shaft, these bearing locknuts can be used. By applying torque to the locking screw, a pressfit or wave spring effect is created, locking the female threads of the locknut to the male threads of the shaft.	
	• Standard diameters and thread sizes available. • No damage is made to shaft or bearing surfaces. • Spanner slots and holes are included.	
 Matching Sets	To gain a better distribution of load, or to increase load capacity without increasing element and bearing size, matched sets are used.	
	• Ensure binding is not experienced with different bore sizes among bearings.	• Even though bearing dimensions are within tolerance, binding can be experienced if deltas are too high.
 Open	An open bearing is one that does not have any shields or protective covers on it.	
	• Allows grease or oil to flow freely through rolling elements. • Can be sealed on one side only.	• Housing must provide: – Protection from debris and contaminants. – Manage lubricant.
 Sealed	Self-lubricating bearings must be factory sealed on both sides.	
	• Holds in grease. • Protects against debris and contamination. • Various seal types available.	• Not normally used with lubricating system.
 Sensorized	Optional sensor senses are available in open-loop or closed-loop control applications that need: • Bearing function and relative position of the inner ring vs. the outer ring. • Acceleration or deceleration, speed and direction of rotation.	
	• Are lubricated for life and maintenance-free. • Take up hardly more space than the bearing. • Require only standard bearing tolerances. • Are insensitive to environmental influences and less prone to corrosion.	
 Shields	Pressed sheet steel on one or both sides of the bearing.	
	• Protects rolling elements from impact damage.	• Adds weight to bearing.

Bearing Attributes	Pros	Cons
 Unground	These low-carbon or stainless steel bearings are semi-precision, with unground inner bore and outer ring surfaces characterized by precision levels less than ABEC 1.	
	• Low cost with the same quality and performance at specified operating range. • Radial, thrust and combination bearings are available.	• Speed and other specifications are generally less than precision ground equivalent, check specifications. • A 10:1 tolerance difference can be expected, e.g. 0.005 vs. 0.0005. • Life ratings are derived from experience and generally not stated.

MOUNTED BEARING STYLES

Many bearings are mounted in a housing. The housing supports the bearing and locates the shaft. It also provides protection for the bearing and, if needed, lubrication ports. This group includes bearings that are factory mounted in flange, pillow block, or other mountings that are ready to use on a machine, appliance or other system. These factory built housings have the advantage of not requiring any special engineering and can be easily bolted or otherwise attached.

Table 36: *Mounted Bearing Types*

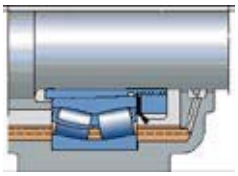
Bearing Types	Pros	Cons
 Flange Mount	Used when a shaft axis is perpendicular to the bearing mounting surface.	
	 Two Bolt The most popular flange mount type. Used in a variety of applications as mid-shaft or end support.	
	• Easily mounted with two bolts.	• May require re-lubrication for some applications. • Locates on one axis.
	 Three Bolt Three bolts are required to mount this flange.	
	• More accurate placement than two bolt flange mount. • Has a better load distribution than two bolt flange mount.	• May require re-lubrication for some applications.
	 Four Bolt Four bolts are used to secure and locate this flange.	
	• Locating is done in two axes. • Has a better load distribution than three bolt flange mount.	• May require re-lubrication for some applications.
	• Available in 2, 3 or four hole configurations with numerous bearing types factory inserted. • Provide a method of accurate mounting fits and load support. • Usually includes grease fitting or grease port. • Allow for positional adjustments. • Available with plain or roller bearing inserts.	• Must be mounted on flat surface. • Replacement usually requires replacing both bearing and flange as a single unit.

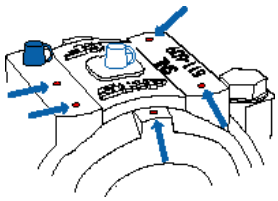
Bearing Types	Pros	Cons
 Pillow Block	Also known as plummer (European term) block, used extensively in used extensively in fabricated equipment.	
	• Easy to fit, maintain and replace. • Sealed and pre-greased, and under normal conditions require no further lubrications • Two types available: standard height and low center height.	• May require re-lubrication for some applications.
 Polymer Bearing Housings	Available in both flange and pillow block styles.	
	• Self-aligning and maintenance free. • Dust, dirt, corrosion and chemical resistant. • Vibration dampening capacity. • Lightweight and easy to install. • Self-lubricating, oil-free operation.	• Too much torque on mounting bolts can damage material. • For use with small loads.

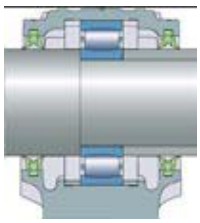
Mounted Bearing Attributes

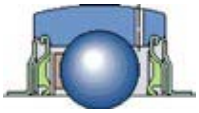
Many options are available to protect, lubricate, and seal bearings and bearing housings. In the case of mounted bearings, many of these attributes can be incorporated into custom designed housings and mounting systems to improve performance. The attribute applied depends on environment, shaft speed and bearing type.

Table 37: *Mounted Bearing Attributes*







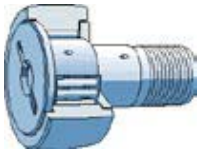
Bearing Attributes	Pros	Cons
 Flinger	Mounted inside or outside the bearing housing. Depending on function, they spin with the shaft and may be attached to the inner ring or directly to the shaft.	
	• Mounted outside the housing to repel dust and dirt. • Mounted inside to pickup and fling oil for lubrication.	
 Lube Ports	Many flange or pillow block housings include one or two lube ports.	
	• For some housings, more ports can be drilled, as marked. • Lube port may inject from top or side of bearing.	• If at top, ensure bearing has outside groove and hole for lubricant to enter bearing.
 Lubricators	Several lubricator systems are available for grease and oil. Oil lubricators, usually require a whole system. Grease lubricators, like the ones shown to the left, can be per individual bearing or mounting. See discussion on Lubrication.	
	• Automatically dispense grease at set rate. • Except for refills, are maintenance free. • Can be directly or remotely mounted, with hose.	• Some systems are battery powered and occasionally need preventive maintenance and replacement.
 Seals	The type of seal used depends on the housing style and the function of the seal.	
	• Seals lubricant in. • Seals dust, debris and contaminants out. • Various styles are available, depending on environment and level of protection.	• Seals can get damaged and may occasionally need replacing. This usually occurs when the shaft is damaged.

TRACK RUNNER BEARINGS

Track runner bearings consist of a bearing with a specially designed outer ring to travel along and guided by a track. The rolling element is typically needle or cylindrical roller because of the long contact area that can better support a shaft laterally. They are available as roller only or with a stud.

Cam Follower

Cam followers are characterized by a thick walled outer ring that enables them to accommodate shock loads while reducing distortion and bending stresses. They are used extensively in applications where rotary motion is converted to linear motion or motion of a specific shape and/or timing.



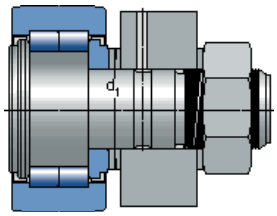


Table 38: *Cam Follower Bearing Types*

Bearing Types	Pros	Cons
 Crowned	Crowned refers to the profile of the outside surface of the outer ring. This surface is slightly bowed and not linear.	
	• Insures a single contact point near the center area of the outside surface. • Increased life over cylindrical (flat) followers.	
 Radial – Thrust	Capable of handling combined radial and thrust loads. They are tightly sealed for use in high moisture or dusty environments. They also run at much higher speeds than needle bearings.	
 Flanged	These are similar to plain cam followers, but with a flange on one side.	
	• With the proper track, can locate laterally and axially.	
 Plain	Basic cam follower, crowned or cylindrical (linear) surface contact.	
	• Easily rides on the flat cam surface.	
 V-Groove	Designed to ride on a V-track.	
	• Can manage radial loads and thrust loads from both directions. • If on a track, only a single track is required.	
	• Capable of handling combined radial and thrust loads. • Tightly sealed for use in high moisture or dusty environments. • Run at much higher speeds than needle bearings.	
 Yoke	Yoke type refers to a studless cam follower that slips over a peg, shaft, bolt, etc.	
	• Easily adaptable to a machine component. • Sealed and self-lubricating with sintered metal plain bearing properties. • Available in bronze, steel, and stainless steel. • Interchangeable with standard needle roller bearing types.	

LINEAR BEARING STYLES

Linear bearings apply plain bearing technology to move components along a linear track with high accuracy and high repeatability. Fluid film lubrication techniques allow high speeds to be accomplished. Oil-Air (Spot) is the most common method of lubrication.

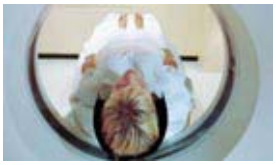


Table 39: *Linear Bearing Types*

Bearing Types	Pros	Cons
 Ball Bushing	Integrated with machine components, open or closed styles run on a shaft to guide motion.  Closed  Open  Closed Pillow Block  Open Pillow Block • Can be mounted in a customized housing. • Travel speeds up to 10 ft/s (3 m/s). • Self-aligning in all directions up to 0.5°. • Coefficient of friction as low as 0.001 • Open style for continuously supported (lubricated) applications. • Wipers keep shaft and bearing clean.	• If exposed, open bushing can collect dust and dirt. Wipers can be damaged.
 Plain	Plain bearing linear slides offer many of the same features as plain bearings earlier discussed.  Inch  Metric  Open  Closed  Pillow Block  Flange • Self-lubricating Teflon© liner and aluminum shell. • Easily adapted to many applications to guide motion. • Open styles provide an easy means of continuous lubrication and are more compact.	• Depending on fit and environment, wipers may be needed to protect bearing and shaft from dust and debris. • Wipers are factory installed and must be specified when ordering.
 Square	Square linear bearings are a low cost alternative to round slide systems. • Bearing plugs are adjustable and replaceable. • Square shaft and mounting components are available. • Two or four sided bearings are available.	• Bearing plugs require Loctite© or other means for locking threads.

Linear Bearing Attributes

Shafts, supports, housings, wipers and other accessories may be needed to complete a linear slide application.

Table 40: *Linear Bearing Attributes*

Bearing Attributes	Pros	Cons
 Accessories	Seals, wipers, retaining rings and other accessories are available. • Seals and wipers are specially designed protect shaft and bearings. • Wipers keep shaft and bearings clean. • Internal and external retaining rings are available.	• Accessories must be matched by manufacture and/or model. Generic snap rings and other fasteners may be dimensionally and otherwise compatible. • Some accessories are factory installed and must be specified when ordering.

Bearing Attributes	Pros	Cons
 Bearing Grease	Linear Lube™ is specially designed for use in bearing applications.	
	• 100% synthetic grease with concentrated Teflon particles. • Will not volitize or oxidize at high operating temperatures or form corrosive deposits. • Contains no petroleum products. • FDA listed and USDA rated H1 and non-polluting. • Effective from -65°F to +450°F (-54°C to 232°C).	• Applicator required.
 Round Shaft	For use with plain and ball bushing bearings.	
	• Precision ground to exacting standards. • Case hardened to 60-65C. • Stainless steel for corrosion resistance, is 440C with a hardness of 50-55C. Chrome plated steel for corrosion resistance. • Surface finish 12 Ra micro inch. • Pre-drilled shafts are available.	• Require sufficient end supports or support rails, depending on loads and application.
  Shaft Support Rails	Linear rails are used with open style plain linear bearings, ball bushings, and pillow blocks to provide a precision linear guided path for mechanical machine motion.	
	• Depending or manufacturer and style, are pre-drilled, come in 12″, 24″ and 48″ (assemblies) lengths available. • Can be laid end-to-end for longer lengths. • Inch and metric sizes available. • Can be ordered as rails only or pre-assembled, or custom made. • Lightweight aluminum alloy.	• To be used with open style bearings. • May need to be cut to length.
  Shaft Support Blocks	Positioned at each end, these off-the-shelf support blocks are easy to install and apply.	
	• Easily secured with mounting bolts. • Malleable iron alloy with corrosion resistant coating. • Can be reamed to accommodate larger shafts. • Flanged mount made of high strength aluminum alloy.	• Must be accurately aligned or shimmed for precise location.
 Square Shaft	Square shafts are used with square linear bearings.	
	• Made of 304 stainless for high corrosion resistance. • Buffed and polished for smooth, quiet operation. • Available in any length up to 10 ft (3 m).	

Custom Products

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Just call the toll-free number listed at the bottom of the page or go online at ReidSupply.com.

Summary

Using the design considerations, data tables and selection information should help with application and selection of Bearings and Power Transmission products for your machine or equipment design and performance. Data tables include material and usage information. Professional standards and government safety regulations improve application design and performance. Product pros and cons allow customers to compare products relative to application specifications. Links send the customer directly to online catalog searches relative to the products listed.

Use of the above information and references listed in Table 41 should ensure the best product selection for proper leveling, noise, shock and vibration control of machines and equipment. This Resource Guide can be viewed online at ReidSupply.com or downloaded and saved as needed at no cost. For comments on the contents of this Resource Guide, contact the Customer Service department using the toll-free number listed at the bottom of the page. Or email us at mail@ReidSupply.com (enter "Resource Guide" in the subject line).

For More Information

Although the Internet offers a vast wealth of information, it may not always be readily available. Much of the information on the Internet and in this Resource Guide comes from professional standards, government regulations and the reference manuals available at Reid Supply, Table 41. Use Table 42 to help select the best reference manual to meet your needs.

Table 41: *Recommended Documentation and Reference Manuals*

Ref #	Title	Cat. No.[1]
1	Machinery's Handbook Pocket Companion	DR-11
2	Machinery's Handbook Guide	DR-12
3	Machinery's Handbook	DR-5CD DR-5C DR-5J DR-5T
4	Machinist's Ready Reference	DR-18
5	Mark's Standard Handbook for Mechanical Engineers	DR-26
6	Standard Handbook of Machine Design	DR-37
7	Materials Handbook	DR-52
8	Engineers Black Book	DR-95

NOTE: [1] Refer to Table 42 for details on content relative to this Resource Guide.

Table 42: *Reference Manual Content Relative to This Guide*

Information Type	DR-5C DR-CD DR-5T DR-5J	DR-11	DR-12	DR-18	DR-26	DR-37	DR-52	DR-95
ABEC/RBEC	2,3,5,9							
ABMA (formerly AFBMA)	2,3,6,9							
AISI classification of aluminum	2,4,7,9	2,4,9		2,4,9	2,4,7,9	5,9	2,9	
AISI classification of tool steel	2,4,7,9	2,4,9		2,4,9	2,4,7,9	5,9	2,9	
Bearing basics	2,3,4,6,9							
Classes of bearings	5,9					4,6,9		
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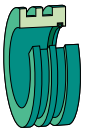
Glossary

Below is a list of terms used in this document.

Term	Definition
Apparent Viscosity	The ratio of shear stress to rate of shear of a non-Newtonian fluid such as lubricating grease, or a multi-grade oil, calculated from Poiseuille's equation and measured in poises. The apparent viscosity changes with changing rates of shear and temperature and must, therefore, be reported as the value at a given shear rate and temperature (ASTM Method D 1092)
Axial	A direction parallel to and along a given axis. For bearings, axial refers to a direction parallel to or along the bearing centerline.
Brinnelling	A condition caused by excessive loading of a ball bearing that exceeds the elastic limits of the steel and the raceways. Brinnelling creates measurable dents at each ball location in the raceway that often generate high noise levels.
Cage	The separator that spaces and holds rolling elements in their proper positions along the races.
Centistokes (cSt)	See Kinematic Viscosity.
Coefficient of Friction	The ratio of the friction between two surfaces to the pressure between them. A low coefficient of friction means low friction losses that are influenced by the viscosity and character of the lubricant and by materials, surface conditions and other factors.
Corrosion	A chemical attack on metals by acids, alkalies, oxygen, chlorine, sulfur or other chemicals. This is distinct from metal destruction by wear and may be evident by either discoloration or pitting.
Delta	A mathematical term used to express an absolute difference in dimensions or values. e.g. -0.002 to +0.005 has a delta of 0.007.
Flingers 	L-shaped metal rings that slide over and onto the shaft. The flinger is positioned outside the seal and rotates with the shaft to fling away any potential contaminants that might otherwise enter the bearing.
Fluid Film	Depending on molecular structure, liquids tend to cling to some surfaces. This cling action forms a film over the surface with a thickness depending on fluid/material properties, viscosity, applied loads and heat. In the case of lubricants, a fluid film that covers the entire surface between moving elements is very favorable.
Fretting Corrosion	Corrosion that can occur on the load bearing contact surface between mating material. It is caused by the combination of corrosion and the abrasive effects of corrosion product debris often seen in equipment with moving or vibrating parts. Other problems induced by fretting corrosion include: surface pitting, seizing and galling of mating surfaces, reduced fatigue life as a result of stress concentrations produced on the metal surface.
Friction	The resistance to motion between two contacting surfaces.
Galling	A form of wear in which seizing or tearing of the gear or bearing surface occurs.
GD&T	Geometric Dimensioning and Tolerances - This acronym refers to a standard set by the ASME and documented in ASME Y14.5M 1994. It is a language of symbols used on mechanical drawings to efficiently, and accurately communicate geometry requirements for features on parts and assemblies. It is almost identical to the Geometrical Product Specifications ISO series and is recognized world wide.

Term	Definition
Journal	A round, smoothly polished, section of shaft.
Journal Bearing	Also known as a shell bearing, plain bearing, or hydrodynamic bearing. This type of bearing is designed to be positioned between bearing housing and the shaft journal.
Kinematic Viscosity	The ratio of absolute or dynamic viscosity to density – a quantity in which no force is involved. Kinematic viscosity can be obtained by dividing the absolute viscosity of a fluid with its mass density: $\nu = \mu/\rho$ Where: ν = Kinematic viscosity; μ = Absolute or dynamic viscosity; ρ = Density. The SI-system theoretical unit is m^2/s or commonly used Stoke (St) where: $1\ St = 10^{-4}\ m^2/s$. Since the Stoke is an unpractical large unit, it is usual divided by 100 to give the unit called Centistokes (cSt) where $1\ St = 100\ cSt$, $1\ cSt = 10^{-6}\ m^2/s$. Since the specific gravity of water at 68.4°F (20.2°C) is almost one - 1, the kinematic viscosity of water at 68.4°F is for all practical purposes 1.0 cSt.
Labyrinth Ring	A non-contact metal ring with radially arranged labyrinth steps that form a narrow sealing gap with the housing grooves. Hollow O-ring cords of silicone rubber (supplied with the seals) ensure that the labyrinth rings, which are mounted with a loose fit, rotate with the shaft.
Lateral	A direction perpendicular to a given axis. Usually referenced to a sideways direction of motion or force vectors. For bearings, this typically refers to a direction perpendicular to the bearing centerline.
Load Rating	A reference standard. Also known as Dynamic Operating Capacity.
Lubricant	A bearing lubricant lubricates the rolling and moving surfaces, protects from corrosion, spreads heat evenly, and inhibits contamination.
Moment	Moment refers to an applied forced which tends to cause an object to rotate about a pivot point. If the force is applied through the pivot point, the object will move and not rotate. Unlike Torque, whose units are lbs-ft (pounds-foot) or N·m (Newton·meter in metric), moment is expressed in the opposite terms ft-lbs (foot-pounds) or m·N (meter·Newton in metric). Also refer to Torque.
OEM	Original Equipment Manufacture - the company that actually designed, manufactured, and assembled the product, equipment or system.
Oxidation	This occurs when oxygen attacks petroleum fluids. The process is accelerated by heat, light, metal catalysts and the presence of water, acids, or solid contaminants. It leads to increased viscosity and deposit formation.
Positive Atmosphere	A technique where dry, clean air is used to increase the internal pressure of a cabinet or other enclosure above that of the external environment. This is a very good method of preventing contaminants and debris from entering.
Race	Refers to the groove or track for which the rolling elements of a bearing follows. Outer and inner rings can have a race. Refer to Figure 1.
Radial	A direction perpendicular to and toward or away from a centerline.
Scoffing	Abnormal wear due to localized welding and fracture. It can be prevented through the use of anti-wear, extreme-pressure and friction-modifier additives.



Term	Definition
Shock Load	A momentary load or movement caused by: • Sudden impact, jerking or swinging of a static or dynamic load. • Delayed release of a static load during initial lifting.
Sintered	An alternative process to casting that causes one or more compounds (metallic powder, for example) to form a coherent mass by heating without melting. e.g. oil-impregnated bronze for bearings.
Spalling	Metal flaking (off) of the race or roller caused by inclusions in bearing steel, misalignment, deflection or heavy loading.
Stoke (St)	See Kinematic Viscosity.
Thrust	A continuous pressure of one object against another, parallel to the centerline.
Torque 	Measured in N·m (Newton-meters) or ft-lbs (foot-pounds), Torque is the resulting radial force (F) applied over a radial distance (R) at, and normal to, the pivot point (P). The equation: T = FR For example: if a force (F) of 10 lbs is applied 2 feet (R) from the center of the pivot point (P), the resulting torque would be 20 ft-lbs; or: 2 ft x 10 lbs = 20 ft-lbs.
Vibration	A rapid linear motion of a particle or of an elastic solid about an equilibrium position. A change of position that does not entail a change of location.
Viscosity	A value expressing a fluid's resistance to flow. It reflects the amount of friction between moving molecules of material in a liquid state. Water has a very low viscosity, where molasses has a higher viscosity.
Wear	Damage resulting from the removal of materials from surfaces in relative motion. Wear is generally described as: Abrasive: Removal of materials from surfaces in relative motion by a cutting or abrasive action of a hard particle, which is usually a contaminant. Adhesive: Removal of materials from surfaces in relative motion as a result of surface contact. Galling and scuffing are the extreme cases. Corrosive: Removal of materials by chemical action.

References

The following is a list of references used to create this document. They are referred to by number, e.g. [3], in the text where applicable.

1] Reference manuals listed in Table 41
2] www.nssn.org
3] SKF
4] EngineersEdge.com
5] Pacific-Bearing
6] Timken Company
7] Bunting Bearing Corp.

Notes

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