Bearing Technical Information

We hope that the **bearing technical information** shown below will help you to gain a better understanding of bearings and their performance. If you require further information or an explanation of any of the sections below, please contact us.

1. Bearing Material

For chrome steel and stainless steel material composition and details on the different grades of stainless steel used in our bearings, please see our material tables

SAE52100 Chrome Steel (no prefix)

This is the standard steel for most ball bearings. It is harder than stainless steel and gives greater life ratings. It also has superior low noise qualities to standard 440 grade stainless steel. Chrome steel actually has a low chromium content and is not corrosion resistant so not suitable for corrosive environments or for dry (no lubricant) bearings as chrome bearings require a protective oil coating on the exterior surfaces which can contaminate the inside of the dry bearing. Chrome steel can tolerate continuous temperatures of up to 120C. Above this temperature, chrome steel undergoes greater dimensional change and the load capacity is reduced. It can withstand up to 150C intermittently but above this temperature, bearing life is reduced..

AISI440 and KS440/ACD34/X65Cr13 Martensitic Stainless Steel (prefix "S")

More resistant to corrosion due to the greater chromium content and the addition of nickel, 440 grade stainless steel is the most commonly used for corrosion resistant ball bearings. The chromium reacts with oxygen in the air to form a chromium oxide layer, known as the passive film, on the surface of the steel. It is hardenable and gives a good combination of strength and corrosion resistance. It is magnetic unlike some 300 grades. The load capacity of 440 grade is approximately 20 percent less than chrome steel so life ratings will be slightly reduced. This grade exhibits good corrosion resistant when exposed to fresh water and some weaker chemicals but may corrode in seawater environments or in contact with many aggressive chemicals. The corrosion resistance also depends on the surface finish. Iron particles and other impurities left on the surface during maching can lead to premature localised corrosion while surface irregularities or poorly finished surfaces also increase the likelihood of corrosion. ***KS440/ACD34/X65Cr13*** grade stainless steel with a lower carbon content is used by EZO Japan and has greater corrosion resistance and superior low noise qualities to the standard AISI440C grade. Corrosion resistance can be increased by passivation (see section below). The 400 grade stainless steel will also ***withstand higher temperatures than chrome steel***, coping with up to 250C constant and up to 300C intermittent with reduced load capacity. Above 300C, bearing life can be considerably shortened.

A note on passivation....

Passivation is a process by which free iron particles and other impurities are removed from the surface of stainless steel by immersion in nitric or citric acid, thus regenerating the passive film. This reduces the likelihood of surface discolouration so making it a useful process in some corrosive environments. Passivation does not increase the resistance of stainless steel to pitting corrosion. This means that where a bearing has incidental contact with, say, salt spray, passivation may be beneficial but it will not offer long term protection in harsher applications.

AISI316 Austenitic Stainless Steel (prefix "S316")

Used for ***greater corrosion resistance*** or where bearings must be ***non-magnetic***, bearings made from this material are semi-precision and fine for applications such as marine pulleys but not suitable for precision instrument use. The main problem here is that 316 grade stainless steel is non hardenable, therefore as a softer steel, it will only support low loads and low speeds. The dynamic load rating of a 316 grade bearing may only be 10% of the 440 grade equivalent whereas the maximum speed may be 5% or less of the 440 stainless steel version. 316 grade stainless steel exhibits good corrosion resistance in sea atmosphere and may perform well submerged in seawater. However, as the passive film on the surface of stainless steel relies on the presence of oxygen to regenerate itself, in a low oxygen underwater marine environment (e.g under washers or o-rings) the steel may be prone to pitting or crevice corrosion although 316 grade is still much more resistant to corrosion than 440 grade. Bearings made from 316 grade stainless steel can be used at high temperatures provided a suitable cage material is used. Due to the difficulty of using 316 grade for the cage, 304 grade stainless steel is normally used for metallic cages and nylon for non-metallic cages. Please remember that, as 316 grade bearings are far less popular, minimum quantities may apply and some smaller instrument bearings may not be available.

Plastic - acetal resin (prefix "AC")

Bearings made from acetal resin with balls made from 316 stainless steel or glass are more corrosion resistant. They will however, corrode in the prescence of certain chemicals for which made-to-order polyethylene or polypropylene bearings with glass balls may be a better choice. These are generally termed as "plastic" bearings and like 316 stainless steel bearings, are not suitable for anything other than low loads and low speeds and should not be used in temperatures of greater than 90C. These types are also low precision so not suitable for instrument use. The smaller bearings are not usually available in these synthetic materials.

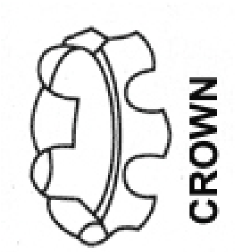
Ceramics - Silicon Nitride (prefix "CB" or "CC")

Some types may be available with steel rings and ceramic balls ***(hybrid)*** or "all ceramic" bearings with ceramic rings and balls. These types may not be stock items and could be subject to minimum order quantities. There are many advantages to silicon nitride such as a ***lower friction coefficient***, much ***greater hardness and temperature resistance***. Silicon nitride has 40 percent of the density of bearing steel but is about twice as hard. The lower density means that the balls exert less force on the outer raceways reducing wear while the extra hardness means greater wear resistance. Hybrid bearings are also capable of higher speeds (usually up to 30 percent) and can also operate better with limited lubrication as the lower friction material generates less heat. However, ceramic bearings can be significantly more expensive, particularly "all ceramic" bearings partly due to the material and partly due to very low production quantities. The cost may be prohibitive for some sizes or quantities.
WARNING: Ceramics are often overrated particularly hybrid bearings.It is often thought that they will provide incredibly high speeds which is not correct unless you use special retainers or no retainer and the bearing still needs to be high quality. Customers often expect very low frictional torque with low noise and vibration levels. This may be possible but the bearing rings must have very good roundness and a high quality raceway finish while the balls must also have very good roundness and surface finish. There are many cheap hybrid bearings on the market that do a worse job than a good quality bearing with steel balls. Good hybrid bearings often prove too expensive for an application. Most sizes are made to order.

2. Retainer

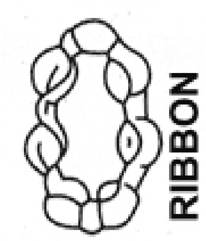
Retainers keep the balls evenly spaced around the raceway preventing ball to ball contact and thus allowing higher speeds. They also help to retain grease around the balls and raceways. For greater accuracy and to prevent any additional friction, it is important that the retainer is not allowed too much radial movement. To achieve this, the retainer is guided by either the balls or one of the rings. See the sections below for information on how each cage type is guided.

Metal crown/ribbon



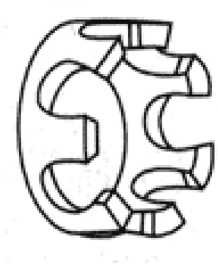
This standard retainer is manufactured from carbon steel for chrome bearings and AISI304 or AISI430 grade stainless steel for stainless bearings. These were often made from brass which also offered a high temperature capability but this is much less common due to higher cost of brass and advances in steel technology.

For higher temperatures, stainless steel is usually recommended. The crown cage and ribbon cage perform the same function but the crown cage is used primarily on smaller miniature bearings and thin-section bearings where space is more limited.Steel cages are preferred for arduous operating conditions and where high levels of vibration are experienced.



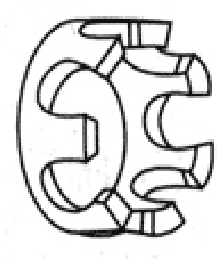
• Good for low to medium speeds
• Can withstand higher temperatures according to the type of steel (see "Bearing Material" section)
• Crown type - inner ring guided
• Ribbon type - mainly ball guided

Nylon crown (TW)



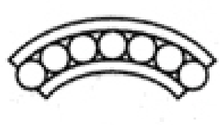
This moulded synthetic retainer has better sliding characterisitics than the steel cage and produces fewer fluctuations in running torque. It can increase maximum speeds by up to 60 percent so is generally used in high speed applications and has good low noise properties. This retainer is not suitable for low temperature applications as it loses elasticity below about 35°C. In vacuum applications, it may become brittle.
• High speed and low noise
• Max temperature range approx -35 to +110°C
• Ball guided

Phenolic crown (TP)



This retainer is also used for high speed applications. Generally more expensive, it does have advantages over the synthetic type such as absorbency allowing it to be vacuum impregnated with oil for long life application.
• Good oil retention.
• Can operate well with marginal lubrication
• Max temperature approx 140°C
• Inner ring guided

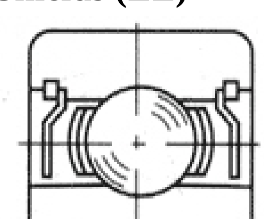
Full complement (F/B)



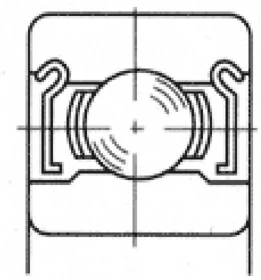
A full complement (or full ball) bearing contains extra balls and has no retainer. It is used for its greater radial load capacity although axial load capacity is very small. These bearings can only be used at low speeds due to ball to ball friction. An exception is a hybrid full complement bearing (ceramic balls) which can be used for very high speeds. Improved steel and hardening techniques have increased the load capacities of bearings with cages and the full complement bearing is much less common now.
• Higher radial load capacity
• Low speed only (except with ceramic balls)
• Low axial load

3. Closures

Shields (ZZ)



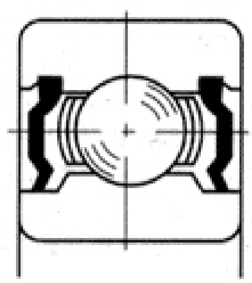
Most sizes are available with metal shields. Shields are designed to prevent larger particles from entering the bearing and also to keep grease inside the bearing. They may be pressed into the bearing's outer ring (non-removable) or retained by a circlip (removable). As the



shields make no contact with the inner ring, they do not increase starting or running torque. Shields on stainless steel bearings are generally made from AISI 304 grade stainless steel.

- Prevent contamination by larger particles
- Reduce lubricant leakage
- No torque increase

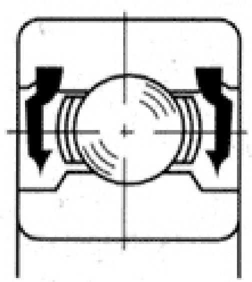
Contact seals (2RS)



The standard bearing seal consists of ***nitrile rubber*** bonded to a metal washer. High temperature ***teflon seals*** (up to 250C) or ***Viton seals*** (up to 230C) are available on some sizes. The inner lip of the seal rubs against the bearing inner ring to provide an effective seal against smaller particles such as dust and moisture while preventing lubricant leakage. Contact seals produce much higher frictional torque levels than shields and reduce the maximum speed of a bearing.

- Good protection against contamination
- Greatly reduce lubricant leakage
- Reduce maximum speed by approx. 40%
- Greatly increase bearing torque
- Temp. range –30°C/+110°C (nitrile rubber) or up to 230C (Viton) and 250C (Teflon)

Non-contact seals (2RU)



These seals are also made of ***nitrile rubber*** bonded to a metal washer but do not rub against the bearing inner ring and therefore do not have the same effect on bearing torque and maximum speed as contact seals so can be used for ***low torque***, ***high speed*** applications. They offer superior protection over metal shields but do not provide as effective a seal as the contact type.

- Good protection against contamination
- Reduced lubricant leakage
- No torque increase
- Do not affect maximum speed
- Temp. range –30°C/+110°C

4. Load Rating

Dynamic load rating

The dynamic load rating is that constant stationary radial load which 90% of a group of identical chrome steel bearings, with only the inner ring rotating, can endure for one million revolutions before the first signs of fatigue develop. ***AISI440C/KS440 stainless steel bearings will achieve approximately 80% of the figure quoted.*** These figures are used in the calculation of life ratings and bearings should not be subjected to such loads in normal application. For life ratings, please contact SMB.

Static load rating

This rating represents the purely radial load which will cause a total permanent deformation of the balls or raceway equal to one ten-thousandth of the ball diameter. This may be tolerable for certain applications but not where smoothness and accuracy are required. Static load ratings for stainless steel bearings are approximately 75% of the load ratings for chrome steel bearings.

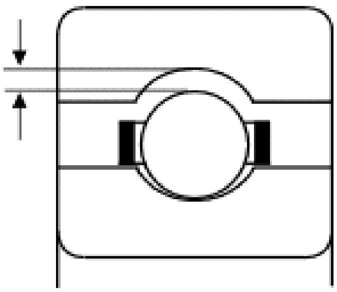
The load capacity of a bearing may be limited by the lubricant. Certain lubricants are only suitable for light loads while others are designed for high load applications. Load ratings are higher for full complement bearings (see Retainer). The axial load capacity of a radial ball bearing can be increased by specifying loose radial play.

Axial load rating

Small and thin-section deep groove ball bearings should not be subjected to axial (thrust) loads greater than 25 percent of the bearing's static load rating. For larger bearings (e.g. 6001, 6201, 6301 upwards) the figure rises to nearer 50 percent. To exceed the recommended limits will have a detrimental effect on bearing life.

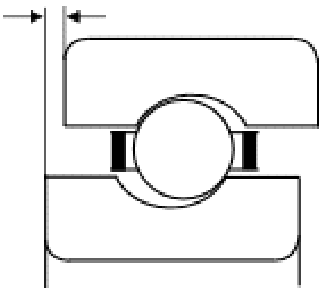
5. Internal Clearance

Radial



Also referred to as radial play, it is the amount of play or looseness between the inner and outer ring or more specifically: average outer ring raceway diameter minus average inner ring raceway diameter minus (2 x ball diameter). Radial play should not be confused with tolerance grade and is entirely separate.

Axial



Clearance measured along the bearing axis is known as axial play. Axial play is approximately 10 times the radial play value.

Internal clearance play may be greatly altered by the mounting conditions of a bearing. Interference fits on shaft or housing can reduce internal clearance by up to 80% of the interference fit. Temperature differentials between shaft and housing can increase or reduce clearance. Changes can also occur as a result of the shaft or housing materials having different expansion coefficients to the bearing steel.

For the actual clearances used in the radial play groups, please see our RADIAL PLAY TABLES.

Tight radial play	MC1/MC2, P02/ P13, C2	Consider for pure radial loads and low noise, low vibration applications. Beware of axial loads, high speed applications, heavy vibration and very low torque applications. Interference fits should not be used.
Medium radial play	MC3/MC4, P24/ P35, CN	Most commonly used and supplied as standard.
Loose radial play	MC5/MC6, P58/ P811, C3/C4	Consider for higher axial loads due to greater thrust load capacity. Greater interference fits and shaft misalignment can be tolerated. Not recommended for low noise applications unless tighter radial play not suitable.

6. Maximum Speed

A number of factors affect speed limitation such as ***temperature, load, vibration, radial play, retainer, lubricant, ball material and closures***. The speeds quoted in our catalogue pages are only approximate and valid for bearings used on a horizontal shaft with a metal cage, standard tolerance grade and radial play, medium loading, rotating inner ring and suitable lubricant (see below). Vertical shaft applications will necessitate a reduction of approximately 20 percent. Temperature excesses and heavy loadings will also require slower speeds. Bearings fitted with contact seals cannot achieve the same speeds due to increased friction between seal lip and bearing inner ring. The choice of lubricant may also have a significant effect on the speed rating. The maximum rpm at which a lubricant can effectively operate varies from type to type. The following adjustment factors are ***approximate*** and are based on bearings with a metal crown or ribbon cage. The maximum speed of a bearing can be increased by the use of a delrin or phenolic cage provided a suitable lubricant is used. The use of ceramic balls will increase bearing speed by up to 30 percent.

Speed reduction Table

	Rotating Inner ring		Rotating outer ring	
	Open/ZZ	2RS	Open/ZZ	2RS
Petroleum oil	Nil reduction	40% reduction	40% reduction	40% reduction
Synthetic oil	Nil reduction	40% reduction	40% reduction	40% reduction
Silicon oil	20% reduction	40% reduction	60% reduction	60% reduction
Standard grease	20% reduction	40% reduction	50% reduction	50% reduction
High speed grease	Nil reduction	40% reduction	40% reduction	40% reduction
Silicon grease	40% reduction	40% reduction	60% reduction	60% reduction

7. Shaft/Housing Fit

Bearing rings under a rotating load may need to be firmly located by an interference fit or other means such as a nut or adhesive. This prevents them from creeping in a circumferential direction which gives rise to increased wear. A bearing ring is subjected to a rotating load when the load is applied to all points of that ring during operation. Tighter fits may also be necessary where vibration occurs. Make sure that interference fits do not reduce the radial play of the bearing to an unacceptable level.

The standards of roundness and surface finish which apply to the bearing should also apply to shaft and housing. This is very important for electric motor and other quiet-running applications. Miniature and thin-section bearings are particularly susceptible to distortion which leads to higher noise and vibration levels. Care should be taken where shaft and housing materials have a different expansion coefficient to the bearing steel (11 x 10 -6 /°C). This may lead to an increase or reduction in radial play.

Interference fits can affect rotational accuracy by distorting bearing rings. If rotational accuracy is important, a combination of close bearing tolerances and close shaft/housing tolerances should be used to obtain the correct fit with the minimum interference. It should also be noted that an interference fit can reduce radial play by up to 80% of the interference fit. ***If further advice on shaft and housing fits is required, please contact us.***

8. Tolerance

Tolerances control the dimensional accuracy of the bearing. ***They have no effect on internal clearance*** although it is sometimes mistakenly thought that improving the tolerances will produce a bearing with less play. Assuming that the shaft and housing are manufactured to the same tolerances as the bearing, higher bearing tolerances will produce better mating between shaft/housing and bearing, lower noise and vibration due to improved roundness and lower starting and running torque (also subject to radial play and lubricant). ***For exact tolerance limits, please view our TOLERANCE TABLES***.

9. Frictional Torque

This affects the free-running of the bearing. Spin a bearing containing stiff grease with your finger and not much happens - relatively high frictional torque. Try a bearing with no lubrication and it will spin freely - low frictional torque. The effort required to rotate a bearing depends partly on the accuracy of the bearing components and raceway finish but much more so on the load and speed applied to the bearing, the lubrication and the closures. The greater the load, the greater the deformation of the bearing components leading to increased resistance. The higher the speed, the greater the lubricant drag. Instrument oils will often produce lower torque levels but the difference between these and many low torque greases is actually quite small, particularly if a low grease fill is used. A standard low torque grease such as Multemp SRL grease may give an increase of only 20 percent over a Aeroshell 12 oil. This can drop to under 5 percent for very low torque greases if a low (e.g 10 to 20 percent) fill is used. Initial torque levels for a greased bearing are briefly higher as the grease takes a short time to "run in" or be distributed inside the bearing. Contact seals will greatly increase the torque figures as will high viscosity lubricants.

Approximate figures for frictional torque for can be calculated using a simple formula. This is only valid if the bearing has low torque lubrication (and the grease fill is not high), is open, shielded or has non-contact seals and is subjected to low speed and low load. For radial ball bearings, the axial load should be less than 20 percent of the radial load while the load should be purely axial for thrust bearings. Contact us if you need more accurate figures taking into account the speed and the lubricant viscosity.

Frictional torque (measured in Nmm or Newton/millimetres)

Radial ball bearings: ***0.5*** x ***0.0015*** x ***radial load in Newtons**** x ***bearing bore (mm)***

Axial ball bearings: ***0.5*** x ***0.0013*** x ***axial load in Newtons**** x ***bearing bore (mm)***

*10 Newtons = 1 Kgf

10. Noise Rating

Bearing rings and balls are not perfectly round and the balls and raceways, even after extensive fine grinding and polishing, are not perfectly smooth. There are machining imperfections in the form of rough or uneven surfaces. For example, if a bearing inner ring is rotating and the outer ring fixed, these imperfections will cause the outer ring to move radially in relation to the inner ring. The amount and speed of this movement contributes to the amount of ***bearing vibration and noise***. Poor cage design can also increase bearing noise.

A low noise/vibration rating is achieved by paying particular attention to the surface finish of the raceways and balls, the roundness of the rings and balls and correct cage design. There are three ratings for low noise bearings: ***EMQ;***, ***EMQ2*** and the quietest, ***EMQ3***. These ratings are independent of precision grade, for example, a P5 bearing may be offered with any of the three noise ratings. To help reduce noise levels even further, low noise greases are available and the choice is now greater due to improved lubricant manufacuring techniques. These greases are more finely filtered and contain fewer, smaller solid particles. These particles generate noise when they pass between the balls and raceway.

External factors such as surrounding vibration can affect bearing noise. Another problem, particularly with smaller and thin-section bearings, as mentioned in "Shaft/Housing Fits" (section 7) is ring distortion caused by poor poor shaft or housing roundness. Dirt or dust contamination will also increase noise and vibration levels. Poor fitting practice or incorrect handling is sometimes to blame, causing shock loads which, in turn, create scratches or dents in the raceway.

11. Lubricants

Correct lubrication is critical to bearing performance, reducing friction, dissipating heat and inhibiting corrosion on balls and raceways. The lubricant will affect maximum running speed and temperature, torque level, noise level and, ultimately, bearing life. Lubricants are available for a whole range of applications. Silicon lubricants have wide temperature ranges and change viscosity less with temperature. They also have good water-resistance but are unsuitable for high loads and speeds. Perfluorinated lubricants withstand temperatures of up to 300°C and are resistant to most chemicals. while certain mineral or synthetic based lubricants are designed for high speed use. Low viscosity oils and greases are used where low lubricant resistance is required but higher viscosity lubricants may be specified for high load applications. Although greases are usually thought to be stiffer than oils, many modern low torque greases can even produce similar torque figures to some of the instrument oils.

- **Oils** – maintain their consistency well over a wide temperature range and are easy to apply. For very low torque applications, a light instrument oil should be specified. Higher running speeds are possible with oil but the obvious drawback with oil is the fact that it tends not to stay in place. For anything other than very low speeds, continuous lubrication through oil mist, oil jet or oil bath is normally necessary. An exception to this is the use of a retainer (cage) that can be impregnated with oil such as the phenolic retainer. Perfluorinated oils can offer improved performance at slightly higher speeds as they don't migrate (run out) as easily.
- **Greases** – are simply oils mixed with a thickener to so that they stay inside the bearing. Greases are generally more suitable for heavy loads and have the obvious advantage of giving constant lubrication over a long period without maintenance. Finely filtered greases are used for low noise applications. Lithium based greases are multipurpose, often low torque and high speed and widely used. Polyurea thickened greases have very good water resistance and a wide temperature range while aluminium complex gives excellent resistance to water washout. Many food applications will require an edible food grade grease. PTFE thickened greases can withstand very high temperatures. Surprisingly, too much grease can be bad for a bearing. A high fill will mean greater rolling resistance (higher torque) which may not be suitable for many applications but worse still is the risk of heat build-up. The free space inside a bearing is important in allowing the heat to radiate away from contact area between balls and raceway. As a result, too much grease can lead to premature failure. The standard fill is 25% – 35% of the internal space but this may be varied if required. A smaller percentage may be specified for low torque, low load applications while a much higher fill may be advisable for a high load application provided the speed is low.
- **Dry Lubricants** – are used primarily in vacuum applications or where standard lubricants are unsuitable. We use molybdenum disulfide for its hardwearing and low friction properties and the fact that it is insoluble in water and dilute acids. It is also effective within a wide temperature range of -180 to +300C. By burnishing the balls and raceways of a bearing, friction is reduced allowing higher speeds than with dry bearings.

We stock many different lubricants but for more information on our standard oils and greases, please see our LUBRICANT TABLES.