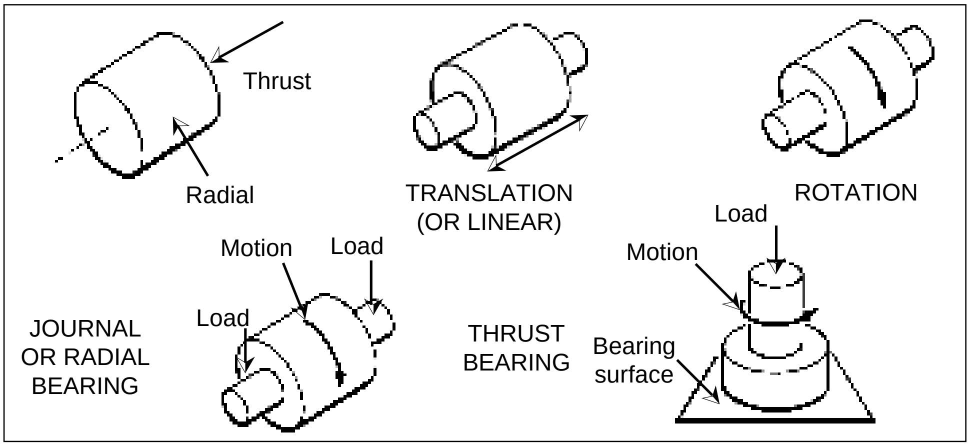
4) Load Bearing Mechanisms

Load bearing mechanisms are the structural backbone of any linear/rotary motion system, and are a critical consideration. This section will introduce most of the more common types of load bearing mechanisms found in linear motion machinery. In general, bearings allow smooth, low friction motion between two surfaces loaded against each other. The motion can be either rotary (such as in a turning shaft) or linear (such as a machine part moving back and forth). Some applications require that a bearing accommodate both types of motion simultaneously, which is referred to as a combination bearing. In both cases there should be a strong attempt to provide enough lubrication to keep the bearing surfaces separated by a film of oil. The absence of physical contact provides most bearings with long service lives.

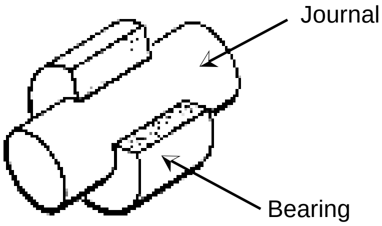
Bearings are evaluated on the basis of how much load they carry, at what speeds they can carry the load, and how long they will serve under those conditions. Friction, start-up torque, shock- and impact-resistance, operating environment, rigidity, size, cost, complexity, and lubricating procedures are also important design considerations.

The following diagram reveals the basic bearing families more widely found in linear motion systems. The distinction between families is made by the type of motion and type of loading being considered. Bearings accommodate rotational and/or translational motion. Translational bearings, or linear bearings, are loaded perpendicular (radial) to the direction of motion. Rotational bearings can be loaded either perpendicular to the axis of rotation (radial) or parallel to the axis of rotation (thrust).



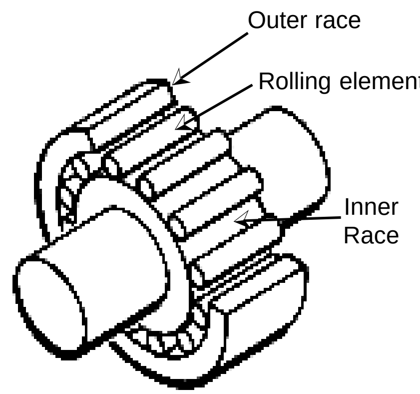
Most bearings can be classified into one of two general types. The distinction between bearing types is made by the nature of the bearing mechanism. The two types each have a number of different possible configurations, and some of the more common configurations will now be discussed. Since many bearings are either specialized or of proprietary design, this discussion is by no means intended to be all exhaustive, but rather to serve as an introduction.

Plain Bearings, or **Journal Bearings**, are the most basic type of bearing. They have no moving parts, they support loads through sliding contact, and are usually the least costly to install. Some plain bearings are self-lubricating and maintenance-free while others are not. In fact, some plain bearings are classified as to the lubricating method required. Typically, plain bearings will operate right up to the point of failure with little or no warning signs. Since the motion involved is usually low level, the results of failure are typically noncatastrophic, and replacement or repair is fairly simple. There are several ways to size plain bearings for an application, as outlined at the end of this section.

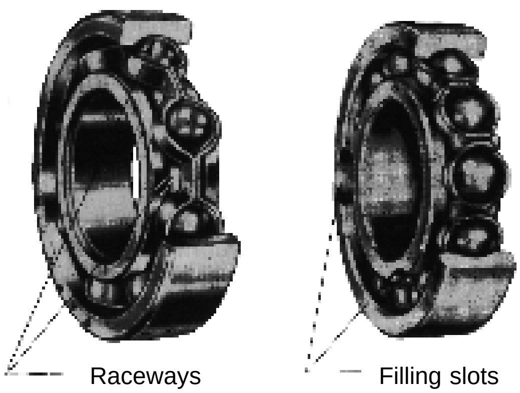


PLAIN BEARING

Rolling Element Bearings, or roller bearings, make up the bulk of commercially available and applied bearings. These types of bearings rely on either balls or rollers to carry the load. The rolling motion produces less friction than found in plain bearings. For this reason, roller bearings are also referred to as antifriction bearings. Both radial loads and thrust loads can be supported by this type of bearing. Lubrication is either permanently sealed in the bearing or is required during operation. The largest causes of failure are either exceeding temperature, load and speed limits, or providing insufficient lubrication during operation. Since roller bearing applications often involve heavy loads and high speeds, failure can be catastrophic, extremely costly and time consuming to repair. Usually there will be an increase in the sound of the balls or rollers in the raceways when approaching failure. There are many different configurations of roller element bearings, and some are discussed in the following section.

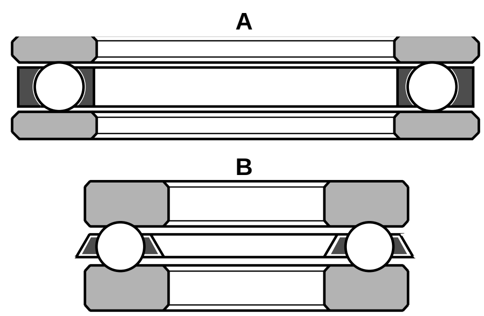


ROLLING ELEMENT



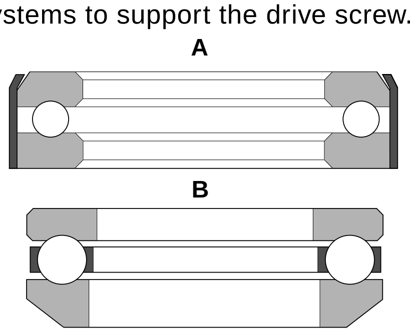
Conrad-type ball bearing, left, and maximum-capacity (filling slot) type, right

Radial Ball Bearings come in two basic variations which are called the *Conrad type*, or nonfilling slot, and the *maximum capacity type*, or filling slot. The Conrad type has a deep, uninterrupted raceway in inner and outer rings. This design is capable of carrying heavy radial and moderate bi-directional thrust loads. The maximum capacity bearing has more balls than an equivalent sized Conrad type, therefore carries a higher radial load. However, the filling slots require that the thrust loads be light and applied only in combination with a heavier radial load. If moderate thrust loads are present, the maximum type can be replaced by a double row Conrad type bearing. Selection of this type bearing is outlined in the following section.

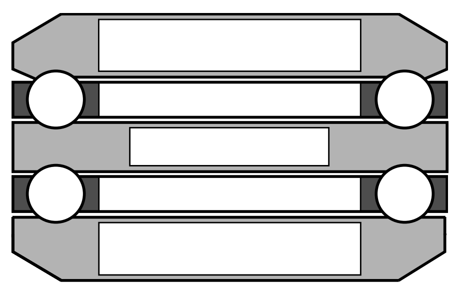


*Flat-race, flat-seat thrust ball bearing, **A**, and grooved-race, flat-seat thrust ball bearing, **B***

Thrust Ball Bearings are designed to provide axial shaft location and support thrust loads. Angular contact ball bearings support radial as well as thrust loads, and the ratio of permissible radial to thrust loads depends upon the angle of contact between the races and the bearing axis. Thrust ball bearings are commonly used in linear motion systems to support the drive screw.



*Banded thrust ball bearing, **A**, and aligning, single-acting, grooved-race thrust ball bearing, **B***



Aligning, double-acting, grooved-race thrust ball bearing

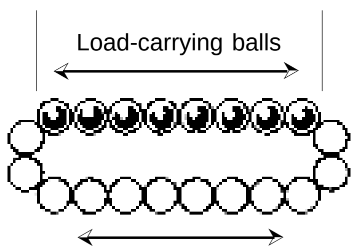
Flat race, flat seat bearings consist of two flat washers and a ball retaining assembly. They are used when the ball retainer assembly must carry thrust loads without restraining shaft oscillations or flexures. They work well with light loads and are very economical.

Grooved race, flat seat bearings are the most common type of thrust ball bearing. They consist of a shaft mounted small bore washer, a large housing mounted bore washer, and a ball retaining assembly. Grooved race bearings have a load bearing capacity approximately 4 times greater than flat race bearings.

Banded thrust ball bearings are self-contained, have grooved races, have a stationary and rotating face with full ball complement, and are encased in a containing band. These bearings are most commonly used where the bearing's outer circumference must be protected from contamination, for blind installation, or where separating forces cause substantial axial motion of bearing components.

Aligning grooved race bearings are a variation of grooved race bearings, and are available in single and double acting types. Aligning members compensate for initial misalignment due to shaft deflection or mismatch, while allowing uniform distribution of the load through the bearing. The double-acting type carries thrust in both directions.

Linear Bearings are most commonly used in linear motion applications. This type of bearing is used when loads are to be supported as the bearing rides back and forth along a shaft. Each raceway holds balls in rolling contact between the shaft and inner bearing race of the bushing. The remaining balls recirculate freely in the back side of the clearance in the ball train sleeve. A retainer is usually provided so that when the bearing is removed from the shaft the balls stay in place. Linear bearings are as easy to install as a plain bearing, while utilizing the advantages of rolling contact. Among the important factors when considering load capacity of a linear bearing system are life expectancy, shaft hardness, and load orientation with respect to the ball trains. Typically, if a lifetime of more than 2,000,000 inches is required, or if a shaft hardness of less than Rc 60 is specified, then the load-carrying capacity of the bearing system will be reduced.



Linear Bearings are the most commonly applied bearing type in linear motion systems. Clearly, many applications involve using two sets of double linear rails, with two bearing blocks on each rail. In this case, the load found on each bearing block is of interest when selecting the bearing components. There are three basic orientations for the bearing system and loads, and each case is represented as follows.

Horizontal Translation with Normal Load: when a normal load is applied to a horizontal bearing system, the loads on each bearing are found by using the following equations. The equations still apply if the load is acting inside of the carriage mounting surface area. The orientation of the applied load with respect to the bearing system is the important feature to consider. This means that these equations can still be used even if the orientation of the translation is not horizontal, as long as the load to bearing relationship is preserved.

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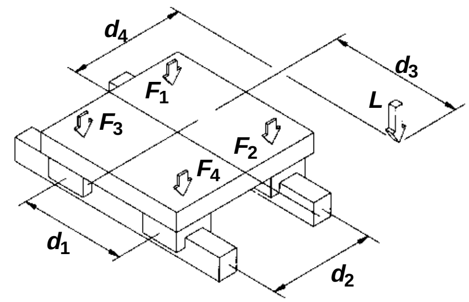
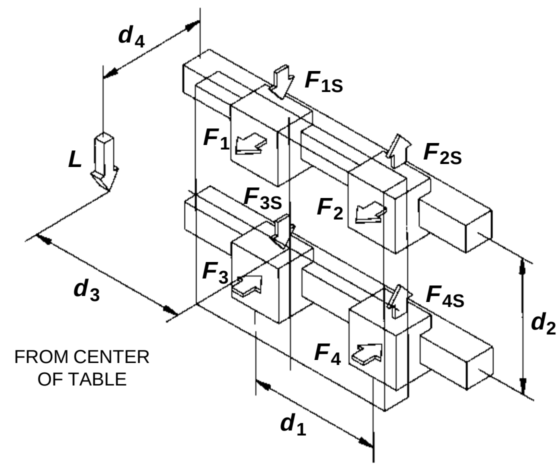
$$\left.\begin{aligned} F_1 &= \frac{L}{4} - \frac{L}{2}\left(\frac{d_3}{d_1} + \frac{d_4}{d_2}\right) \\ F_2 &= \frac{L}{4} + \frac{L}{2}\left(\frac{d_3}{d_1} - \frac{d_4}{d_2}\right) \\ F_3 &= \frac{L}{4} - \frac{L}{2}\left(\frac{d_3}{d_1} - \frac{d_4}{d_2}\right) \\ F_4 &= \frac{L}{4} + \frac{L}{2}\left(\frac{d_3}{d_1} + \frac{d_4}{d_2}\right) \end{aligned}\right\} \quad (7)$$



FORMAT 1

***Horizontal Translation with Side Load*:** when a side load is applied to the bearing system, the loads on the individual bearings change, and new equations are required. Each bearing will have a resultant normal load as well as a side load. The orientation of the applied load with respect to the bearing system is the important feature to consider. This means that these equations can still be used even if the orientation of the translation is not horizontal, as long as the load to bearing relationship is preserved.

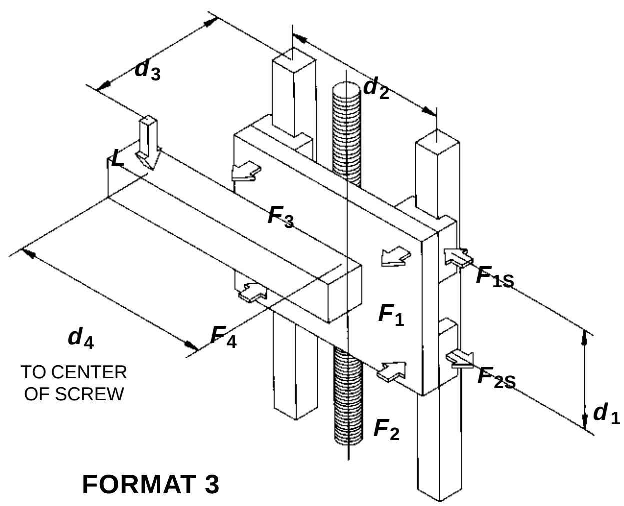
$$\left.\begin{aligned} F_1 = F_2 &= \frac{L}{2}\left(\frac{d_4}{d_2}\right) \\ F_3 = F_4 &= -\frac{L}{2}\left(\frac{d_4}{d_2}\right) \\ F_{1S} = F_{3S} &= \frac{L}{4} + \frac{L}{2}\left(\frac{d_3}{d_1}\right) \\ F_{2S} = F_{4S} &= \frac{L}{4} - \frac{L}{2}\left(\frac{d_3}{d_1}\right) \end{aligned}\right\} \quad (8)$$



FORMAT 2

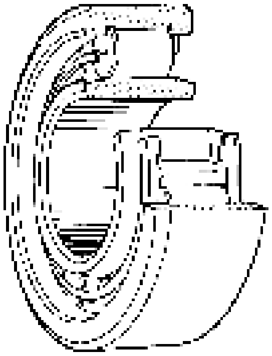
***Vertical Translation with Vertical Load*:** when the load is applied in the direction of travel (thrust), then the following equations should be used to calculate the loads on each bearing block. This type of configuration is generally found in vertical applications. The orientation of the applied load with respect to the bearing system is the important feature to consider. This means that these equations can still be used even if the orientation of the translation is not vertical, as long as the load to bearing relationship is preserved.

$$\left.\begin{aligned} F_1 = F_3 &= \frac{L}{2}\left(\frac{d_3}{d_1}\right) \\ F_2 = F_4 &= -\frac{L}{2}\left(\frac{d_3}{d_1}\right) \\ F_{1S} = F_{3S} &= \frac{L}{2}\left(\frac{d_4}{d_2}\right) \\ F_{2S} = F_{4S} &= -\frac{L}{2}\left(\frac{d_4}{d_2}\right) \end{aligned}\right\} \quad (9)$$

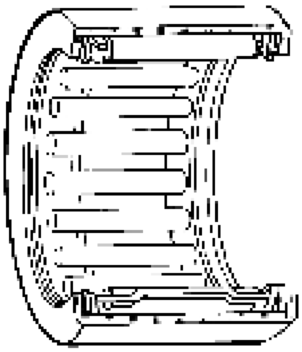


FORMAT 3

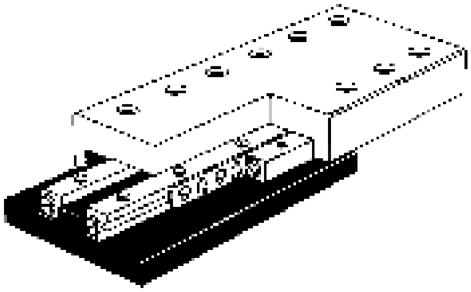
Roller Bearings are also widely used in linear / rotary motion applications. There are several principal types of roller bearings. In general, they have higher load capacities than ball bearings of the same size due to the increased area of contact and, except for the cylindrical type, lower speed capabilities. They are commonly used in heavy-duty moderate-speed applications; and, as with ball bearings, there are many different styles to choose from. Because of the geometry, roller bearings are not tolerant of shaft misalignment.



Cylindrical Roller Bearing



Needle Bearing Caged



Crossed Roller Bearing

Cylindrical Roller Bearings have the highest radial load capacity for a given cross section, and the highest speed capability for any given roller bearing type. A common problem encountered is roller skidding, which causes premature failure. Solutions include a slightly concave raceway that pinches the ends of the rollers, or the use of hollow preloaded rollers to hold position.

Needle Roller Bearings are similar in appearance to cylindrical roller bearings, but typically have a much smaller diameter to length ratio. They typically exhibit higher load capacities than single row ball bearings of comparable OD, and can nearly fit into the same space as a plain bearing. In most instances, a hardened shaft acts as the bearings inner race, although an inner race can be supplied when the shaft cannot be hardened.

Crossed Roller Bearings are very common in heavy-duty precise applications; however, they are extremely sensitive to contaminants. The principle is similar to that of cylindrical bearings; however, the roller diameter must be equal to the roller height. The rollers take on an alternating pattern, with their orientations being crossed at 90 degrees. This arrangement allows very smooth motion, and large load capabilities in all directions normal to travel. A further benefit of crossed roller bearings is very high straight line accuracy.

Selecting and Sizing Bearing Systems

When selecting and sizing bearings for an application, there are several considerations. Most bearing applications can be practically analyzed by sizing load and speed requirements. This section is intended to provide a basic understanding of the bearing selection process, and should not used as an only source.

Plain Bearing Selection: A plain bearing's load capacity is generally expressed as pounds per square inch (psi) of projected bearing area. The size and material of the bearing determine most of the load carrying ability, and there are several rules of thumb to use as a guide.

> *Maximum load capacity for static or very low-speed applications is 1/3 the bearing materials compressive limit. The compressive limit is the lowest pressure that results in plastic (permanent) deformation.*
>
> *Most plain bearings carry less than 400 psi.*

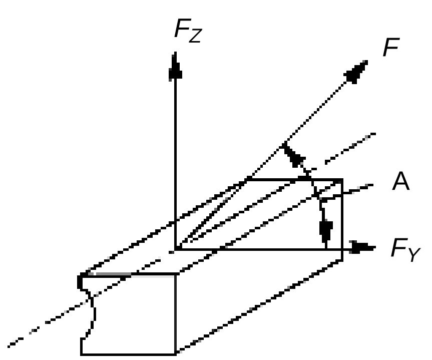
Plain bearings rarely ever carry more than 3000 psi.

Another way of determining a bearing's load capacity is through maximum PV factor. This is the value of pressure on the bearing (psi) times the shaft speed (feet/min).

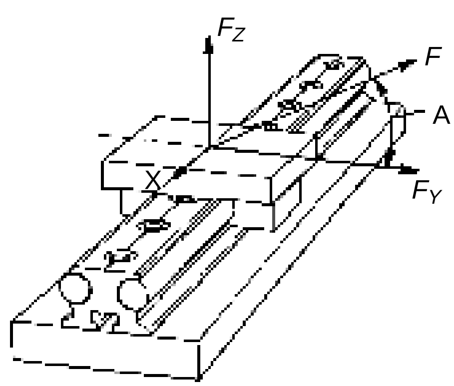
If the PV value for the application is less than the maximum PV value for the bearing considered, and if the application pressure load does not exceed the compressive strength of the bearing material, and if the application speed does not exceed the maximum permissible speed of the bearing considered, then the bearing considered may well serve the application.

Ball Bearing Selection: The nature of the application load must be known and compared to the load carrying capability of the considered bearing. Combination loads should be converted into a single equivalent radial or thrust load using manufacturer's equations to size the application requirement. Regarding speed requirements, tolerance grade, lubrication, retainer design and bearing seal type must be considered, and the maximum application speed must not exceed the maximum allowable bearing speed. A useful guide for ball bearing selection is to consider the DN value (speed value) of the bearing. The DN value is the product of the bore size (mm) and the shaft speed (rpm). This quantity will suggest the type of lubrication and tolerance grade required. Use for the ball bearing type include applications involving shafts that may be slightly misaligned.

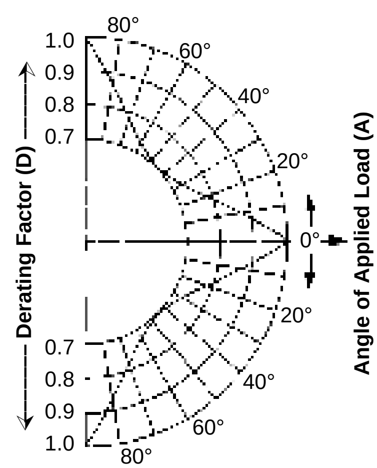
Linear Ball Bearing Selection: This selection is generally based on speed and load requirements. Understanding the orientation and magnitude of the application loads on the bearing is of paramount importance. Most manufacturers and suppliers of such bearings will include information regarding the load capabilities with respect to load orientation, as shown below.



Force on Single Bearing



Force on Double Bearing



Series 1 Bearings

Roller Bearing Selection: Load, speed, and shaft alignment are the most important features to consider when selecting roller bearings. It is suggested that, in the case of needle bearings, the shaft parallelism be less than 0.0003" for the entire length of the bearing section. Further, the shaft should be round to within 0.0002" or to within half the shaft tolerance.

Previous RFQ Page Next Index Page Home Page

Selecting A Linear Bearing System

There are several factors in selecting a Linear Bearing System.
Here are the main items to consider ...

- Travel
- Load
- Orientation
- Maximum Speed
- Minimum Acceleration
- Environment

Nominal Life Expectancy

The nominal life expectancy is achieved, or exceeded a majority of 90% of the nominal life expectancy, before the first indication of fatigue of material appears.

$$L = \left(\frac{C}{P}\right)^x \qquad (1)$$

$$L_h = \frac{833}{H \cdot n_{osz}} \left(\frac{C}{P}\right)^x \qquad (2)$$

$$L_h = \frac{1666}{V} \left(\frac{C}{P}\right)^x \qquad (3)$$

L [m]	nominal life expectancy in 100,000 m
L_h [h]	nominal life expectancy in operating hours
C [N]	dynamic load data
P [N]	dynamic equivalent load
x	life expectancy index:
	ball-bearing linear guides: x = 3
	roller-bearing linear guides: x = 10/3
H [m]	single stroke length of the oscillated movement
n_{osz} [min]	number of the double strokes per minute
V [m/min]	average travel speed

Usable Life

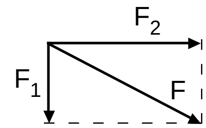
The actual life expectancy achieved by a linear guide is known as usable life. The usable life can deviate from the calculated life expectancy.

Wear & tear or fatigue can lead to early defects:

- alignment error between the guide rails or the guide elements
- insufficient lubrication
- oscillated movement with very small strokes (rippling)
- vibration during standstill (rippling)

Due to the variation in installations and operating conditions, it is not possible to determine the exact usable life of a linear guide in advance. The safest method to obtain a correct assessment of the usable life is to compare cases with similar installation.

Combined Loading Capacity



(4)

When the loading direction of an element does not coincide with one of the main loading directions, the equivalent load is calculated as follows:

$$P = |F_1| + |F_2| \qquad (5)$$

When a Force (F) and a moment (M) are applied at the same time, the dynamic equivalent load is:

$$P = |F| + |M| \cdot \frac{C_0}{M_0} \qquad (6)$$

P [N]	dynamic equivalent load
F [N]	applied force $= \sqrt{F_1^2 + F_2^2}$
F_1 [N]	vertical components, see sketch (4)
F_2 [N]	horizontal components, see sketch (4)
C_0 [N]	static load in the direction of the applied force
M [Nm]	applied moment
M_0 [Nm]	static moment in the direction of the applied moment

According the DIN, the dynamic equivalent load should not exceed the value P= 0.5 ▪ C

For multiple Rail and Carriage Configurations, refer to page 14

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Linear Bearings Application Worksheet

Name: ______________________ Phone: ______________________

Company Name: ______________________ Fax: ______________________

Address 1: ______________________

Address 2: ______________________

City: ______________________ State: __________ Zip: __________

Brief Description of Application: ______________________

____

E-mail: ______________________

Please use this area for any notes or diagrams:

Max Load: ______________________

Max Speed: ______________________

Max Accel: ______________________

Travel: ______________________

Complete Cycle Time: ______________________

Environment (woodshop, cleanroom, etc...): __________

____

Travel Accuracy Needed: ______________________

Orientation of Load: ______________________
(Format 1, 2, 3) *See page 14*