Nook Industries manufactures a full range of linear slide systems and slide systems components. The PowerTrax™ line of linear components includes solid shell LBB linear bearings, self-aligning EXCEL™ linear bearings, HG Hardened and Ground Shafting, Pillow Blocks and complete slide systems.

LINEAR BEARING TYPES

EXCEL™ LINEAR BEARINGS
Designed to fit into precision bores, these bearings are self aligning and offer long life. Precision hardened and ground bearing plates with conforming ball tracks are contained in a molded thermoplastic housing.

LBB
These bearings are used in lower load applications where self alignment is not required. The precision fit between the bearing and shaft is built into the bearing as a result of the solid steel shell. These bearings utilize a molded plastic ball retainer assembled inside a hardened and ground shell.

ILBB INSTRUMENT SERIES
Similar in construction to LBB linear bearings, Instrument Series Linear Bearings are small diameter, high precision bearings with stainless steel shells. When matched with Instrument Series Linear Shafting, ILBB Linear Bearings provide high performance with .0001 to .0003 inch clearances.

ILBB Linear Bearings are used in light load, high precision applications where low friction guidance is required such as medical and semiconductor equipment.

OPEN SERIES BEARINGS
For applications requiring fully supported shafts, "open" bearings are available in both LBB and EXCEL™ types. In an open bearing, one ball circuit is removed to allow the mounted bearing to translate along a supported shaft.

SEALS
LBB and EXCEL™ bearings are available in sealed and unsealed versions. ILBB bearings are unsealed.

MATERIALS
Nook PowerTrax™ linear bearings use a combination of high performance thermoplastic, chrome-steel bearing balls, and either a one piece hardened steel shell or precision ground hardened steel bearing plates. **(SEE FIG. 1)**

EXCEL™ MAXIMUM SPEED
When used in high speed or high impact environments, EXCEL™ bearing capacities should be de-rated as shown in the chart. Divide the rated load by the load factor to determine the appropriate bearing size. **(SEE FIG. 2)**

LINEAR SHAFTING

MATERIAL
Nook PowerTrax™ HG Shafting, made from high quality alloy steel, is manufactured and stocked for immediate shipment in our Cleveland, Ohio facility, in diameters from 5 to 80mm and 1/4 to 4 inches. Stainless Steel shafting is available from 1/4 thru 2 inch diameter.

Standard diameters can be cut to your specified length and shipped within 24 hours of receipt of your order. Contact Nook Industries, Inc. for availability of special diameters.

CASE HARDNESS
PowerTrax™ HG alloy shafting is induction hardened to Rc 60-63. Stainless steel shafting is hardened to Rc 50-55. Instrument Series Shafting is hardened to Rc 55-60. The case depth on all PowerTrax™ HG Shafting is precisely controlled for optimal performance. The extremely hard surface minimizes wear and is resistant to nicks and scratches. **(SEE FIG. 3 on following page)**

FIG.1

FIG.1	OUTER SHELL	BALLS	BEARING PLATE	BALL RETAINER	END RINGS	INTERNAL SEALS
EXCEL™ SELF-ALIGNING	Plastic Resin NYLON-66	Hardened Chrome Steel	Hardened Steel	N/A	N/A	Nitrile
LBB SERIES	Hardened Steel Black Oxide	Hardened Chrome Steel	N/A	Acetal Resin	Steel Black Oxide	Nitrile
STAINLESS STEEL SERIES	Stainless Steel	Hardened Chrome Steel	N/A	Acetal Resin	Stainless Steel	N/A
INSTRUMENT SERIES	440C	440C	N/A	Acetal Resin	Stainless Steel	N/A

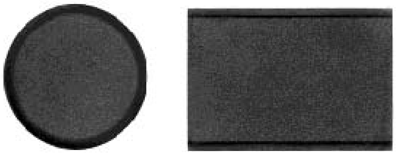
FIG.2

IMPACTS & VIBRATIONS	SPEED	ACCELERATION (G)	LOAD FACTOR (f)
Without external impacts or vibrations	Velocity ≤ 50 ft/min	Acceleration < 0.5G	1 ~ 1.5
Without significant impacts or vibrations	Velocity > 50 ft/min and ≤ 190 ft/min	Acceleration > 0.5G and ≤ 1.0G	1.5 ~ 2.0
Without external impacts or vibrations	Velocity > 190 ft/min	Acceleration > 1.0G and ≤ 2.0G	2.0 ~ 3.5

LINEAR SHAFTING AND LINEAR SLIDE SYSTEM FEATURES

FIG. 3

HARDENED SHAFT CROSS SECTION



END HORIZONTAL

SURFACE FINISH

PowerTrax™ HG shafting is centerless ground to a consistently smooth surface finish of 14 micro-inches rms or less. Excellent surface finish and hardness maximize the efficiency and life of linear bearings.

STRAIGHTNESS

PowerTrax™ HG shafts are straight within 0.002 of an inch per foot cumulative when shipped from the factory. Handling or machining of shafting can cause the material to bend.

PREDRILLED & TAPPED HOLES

PowerTrax™ HG alloy shafting is stocked with radial holes drilled and tapped to accept a continuous shaft support rail. Continuous support prevents shaft deflection when used to support heavy loads or for long travel lengths. Radial holes can be supplied in stainless steel shafts from 1/2" to 2" diameter.

PRECISION END MACHINING

PowerTrax™ HG shafting can be supplied pre-machined to application requirements. Send a detailed sketch or blueprint for a prompt quotation. See page 212 for descriptions of machining offered by Nook Industries. Templates for machining are available on our website—www.nookindustries.com

LENGTH TOLERANCE

PowerTrax™ HG shafting cut to your specified length will have a standard length tolerance of +1/32" up to 2" and ±1/16 above. Closer tolerances are available for an additional charge. Non-precision chamfered ends are standard on all cut shafting.

SHAFT SUPPORTS

Aluminum support components for end mounting or continuously supporting PowerTrax™ HG shafting are available for inch sizes 1/2" to 2".

SELF-ALIGNING PILLOW BLOCKS

PowerTrax™ Pillow Blocks simplify mounting of PowerTrax™ Linear Bearings. They are available with EXCEL™ Bearings to fit shafts from 1/4 to 2 inch and 10 to 50mm. PowerTrax™ Pillow Blocks provide the precision bearing bores necessary for linear bearing installation.

MOUNTING TOLERANCES

The PowerTrax™ Pillow Block mounting surface to centerline dimension is held to ±0.001 inch. Bearings will self-align up to ±1/2°.

MATERIALS

All PowerTrax™ Pillow Blocks are manufactured from precision machined, thick walled, extruded aluminum.

PILLOW BLOCK SEALS

PowerTrax™ Pillow Blocks are supplied complete with lip seals. The sealed pillow block keeps lubricant in and dirt and debris out resulting in smoother operation and longer bearing life.

LINEAR SLIDE SYSTEMS

SERIES 100 SLIDE SYSTEMS

PowerTrax™ Series 100 slide systems are pre-assembled and ready to mount. Series 100 slides consist of combinations of PowerTrax™ Linear Ball Bearing Pillow Blocks, HG shafting, carriage plates and shaft supports. Aluminum carriage plates include threaded steel inserts at key mounting locations.

SERIES 200 SLIDE SYSTEMS

PowerTrax™ Series 200 slide systems are assembled slides which include:

- Linear bearing pillow blocks
- Integrated end supports
- HG linear shafts
- Carriage Plate
- PowerTrac™ Ball Screw assembly

Many options are available for these slide systems. Different screw styles and leads, protective boots, special motor mounts and custom carriage plate machining is available. Contact Nook Industries, Inc. for assistance.

MM SLIDE™ MINI SLIDE SYSTEMS

PowerTrax™ MM Slides™ are metric-dimensioned compact slide units. They utilize lightweight aluminum components and include an integrated carriage/pillow block assembly for a reduced overall height. A wide variety of screw diameters, leads and nut styles are available. These systems include:

- EXCEL™ linear bearings
- Integrated end supports
- HG linear shafts
- Carriage/pillow block assembly
- 1 Lead screw assembly

BEARING DESIGN CONSIDERATIONS

APPLICATION VARIABLES

To determine the best linear bearing product or system for your application it is necessary to know:

- Amount of load
- How the load is applied
- Length of stroke

COEFFICIENT OF FRICTION

PowerTrax™ linear bearings exhibit an extremely low coefficient of friction ranging from 0.0008 to 0.0035. Coefficients of static and rolling friction are used to estimate the force required to overcome frictional resistance.

The formulas for determining static and rolling frictional resistance are:

Static Friction:

$$F_s = L \times f_s$$

Rolling Friction:

$$F_d = L \times f_d$$

WHERE:

F_s = Static frictional resistance (lbs)

F_d = dynamic frictional resistance (lbs)

L = applied radial load (pounds)

f_s = coefficient of static friction

f_d = coefficient of rolling friction

The tables show the coefficients of friction for PowerTrax™ Linear Bearings operating on hardened and ground shafts of recommended diameters. **(SEE FIG. 4)**

There are other variables that affect the dynamic frictional resistance of linear bearings. These variables include:

Lubrication – Dry linear bearings exhibit the lowest coefficient of friction. Friction values for lubricated bearings are higher due to the presence of lubricant surface tension.

Seals – Non-linear seal drag occurs because of the geometry and the materials used in the bearing seals.

Contamination – Foreign particles restrict free rolling of the bearing balls and will contribute to an increase in dynamic frictional resistance.

LUBRICATION

A lubricant formulated for rolling friction should be used with PowerTrax™ Linear Bearings.

In applications where operating speeds are low and loads are light, PowerTrax™ linear bearings can be used without lubrication at a reduced life. However, to protect the highly polished bearing surfaces from corrosion and wear, a lubricant is recommended.

Where linear speeds are high, a light oil should be used and provision for re-lubrication should be made to avoid operating the bearings dry. For typical applications, a medium to heavy oil has good surface adhesion and affords greater bearing protection.

Linear Bearings 2" diameter and above may use high pressure lithium grease such as Shell Alvania #2 for moderate speed applications. Lubricants containing additives such as molydisulfide or graphite should not be used.

Nook Linear Lube LBL-1 liquid is a good, all purpose lubricant for use with linear bearings. See page 239 for more information.

MAXIMUM AND NORMAL LOAD RATINGS

The required design life, the shaft hardness, and a bearing dynamic load rating affect the load that can be applied to a PowerTrax™ linear bearing. Two dynamic load ratings are given for each bearing size based on the rotational orientation of the bearing.

Normal Load Rating – The Normal Load Rating is used in applications where the orientation of the ball tracks relative to the load cannot be controlled. The Normal load rating is based on a load imposed directly over a single ball track. The Normal load rating shown in the specification tables is slightly greater than would be mathematically calculated based on one track loading because it assumes that the load is shared to some degree by one or more of the adjacent ball tracks.

FIG.4

Coefficients of Static Friction (f_s)

TYPE OF BEARING LUBRICATION	LOAD IN % OF RATED LOAD			
	100%	75%	50%	25%
ANY	.0024	.0026	.0029	.0035

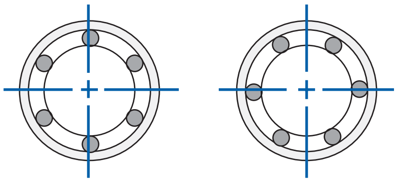
Coefficients of Rolling Friction (f_d)

TYPE OF BEARING LUBRICATION	LOAD IN % OF RATED LOAD			
	100%	75%	50%	25%
NONE	.0008	.0009	.0013	.0018
OIL	.0012	.0013	.0016	.0021
GREASE	.0013	.0015	.0019	.0026

BEARING DESIGN CONSIDERATIONS

Maximum Load Rating – The Maximum load rating assumes that the load is applied midway between two ball tracks as illustrated below. In this orientation the load is distributed over the maximum number of bearing balls. **(SEE FIG. 5).**

FIG. 5



NORMAL LOAD

MAXIMUM LOAD

LOAD LIFE DETERMINATION

The Normal and Maximum load ratings are based on a Rc 60 shaft hardness and a travel life of two million inches.

For linear bearing system operating at less than full rated load, the Load-Life Curve may be used to determine the travel life expectancy. **(SEE FIG. 6)**

SHAFT HARDNESS

If shafting other than standard alloy PowerTrax™ HG shafting is used, the Shaft Hardness Curve establishes a shaft hardness correction factor, Rh. When calculating the equivalent load, this factor compensates for the effect of hardness. **(SEE FIG. 7)**

EQUIVALENT LOAD

An equivalent load value can be calculated when sizing linear bearings for applications at conditions other than maximum rating.

Equivalent Load Formula:

$$L_e = L_a / (R_L \times R_h)$$

WHERE:

L_e = Dynamic Equivalent Load (The minimum bearing capacity to meet design life requirements)

L_a = Applied Load (Actual Load)

R_L = Load Life Ratio Factor (from chart)

R_h = Shaft Hardness Ratio Factor (from chart)

BEARING INSTALLATION

In most installations, PowerTrax™ linear ball bearings are designed to slip-fit into the housing bore and secured by one of the following means:

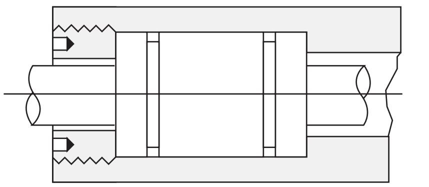
Between an internal housing shoulder and a threaded cap.

Between external retaining rings.

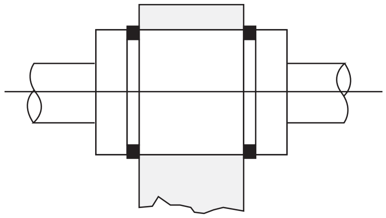
Between internal snap rings in the bore of the housing.

The bore diameter required to maintain recommended bearing/ shaft clearance is given in the EXCEL™ linear bearing information section. The bore does not affect clearance between an LBB bearing and a shaft. **(SEE FIG. 8)**

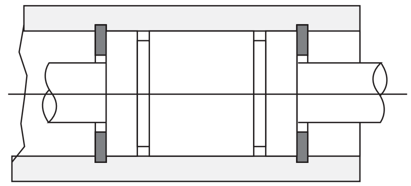
FIG. 8



Between an internal housing shoulder and a threaded cap.



Between external retaining rings.



Between internal snap rings in the bore of the housing.

FIG. 6

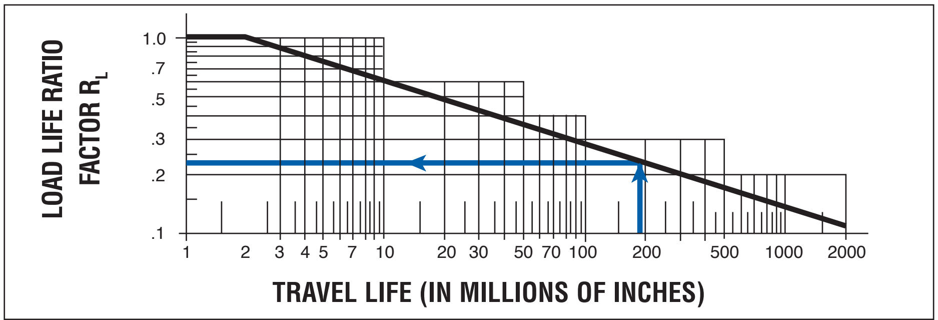
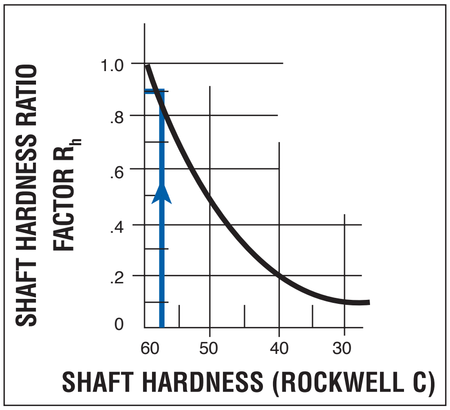


FIG. 7



ASSEMBLY EXCESSIVE FIT

Oversized shaft diameters or misalignment between the installed bearings can cause preload between the shaft and the bearing. Preload conditions should be corrected before operating the bearing. If, in an assembled unit, the shaft can freely rotate relative to the bearing, then the fit is at the maximum or less.

SYSTEM DESIGN CONSIDERATIONS

SYSTEM CONFIGURATION

PowerTrax™ Linear Slide Systems are available in a variety of configurations. The following factors should be considered when choosing the slide system which best suits an application.

SINGLE OR DOUBLE SHAFT SYSTEMS

The majority of applications require double shaft systems in order to restrain the load in two planes. Single shaft systems may be used for hanging or vertical loads where rotation of the bearing around the shaft is allowable.

FULLY SUPPORTED OR UNSUPPORTED SHAFTS

Fully supported systems are used to eliminate shaft deflection. Full shaft supports must be attached to a machined mounting base. Open-style bearings used with this system are sensitive to load orientation.

End-supported systems are generally used to span a gap or where some deflection is allowable. This system uses closed-style bearings that achieve higher load capacities. The shaft must be selected so that deflection does not exceed self-alignment capability of the bearing.

LINEAR BEARING PILLOW BLOCKS

Two bearings must be used to support a load on a shaft. Single blocks allow for custom spacing and wider load bearing stances. Twin pillow blocks have a compact, one-piece design.

CARRIAGE PLATES

Carriage plates are designed in two styles for linear system packages. Carriage 1 is designed for two pairs of single bearing blocks. Carriage 2 is designed for two twin bearing blocks and has a shorter over all length.

BEARING/SHAFT SIZE

For fully supported systems the bearing size needed for the application is determined by the load and life requirements.

For end-supported systems, both the bearing diameter that meets load and life requirements and the shaft diameter that results in an allowable deflection must be determined. The correct choice of shaft/bearing diameter is the larger of the two.

LOAD CONDITIONS

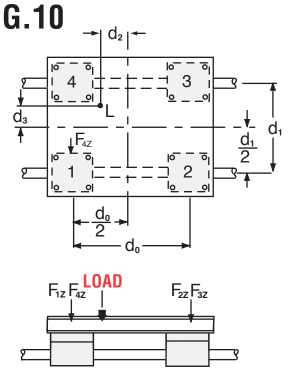
Linear systems require at least three bearings to define the plane of motion. It is necessary to identify and understand which of following load conditions affect the application:

- Centered Loads
- Offset loads
- Side Loads
- Vertical Loads
- Gravity effects
- Reaction Forces (i.e., cutting tool reaction).
- Dynamic loading (acceleration, deceleration and inertial loads)

Apply the actual load to the appropriate load condition in the figure below to calculate the resulting bearing loads. **(SEE FIG. 10)**.

FIG.10

LOAD CENTERED



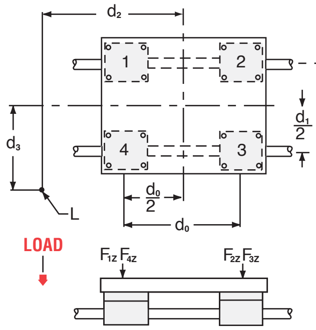
$$F_{1Z} = \frac{L}{4} + \left(\frac{L}{2} \times \frac{d_2}{d_0}\right) - \left(\frac{L}{2} \times \frac{d_3}{d_1}\right)$$

$$F_{2Z} = \frac{L}{4} - \left(\frac{L}{2} \times \frac{d_2}{d_0}\right) - \left(\frac{L}{2} \times \frac{d_3}{d_1}\right)$$

$$F_{3Z} = \frac{L}{4} - \left(\frac{L}{2} \times \frac{d_2}{d_0}\right) + \left(\frac{L}{2} \times \frac{d_3}{d_1}\right)$$

$$F_{4Z} = \frac{L}{4} + \left(\frac{L}{2} \times \frac{d_2}{d_0}\right) + \left(\frac{L}{2} \times \frac{d_3}{d_1}\right)$$

LOAD OFFSET



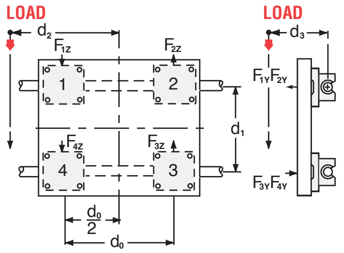
$$F_{1Z} = \frac{L}{4} + \left(\frac{L}{2} \times \frac{d_2}{d_0}\right) - \left(\frac{L}{2} \times \frac{d_3}{d_1}\right)$$

$$F_{2Z} = \frac{L}{4} - \left(\frac{L}{2} \times \frac{d_2}{d_0}\right) - \left(\frac{L}{2} \times \frac{d_3}{d_1}\right)$$

$$F_{3Z} = \frac{L}{4} - \left(\frac{L}{2} \times \frac{d_2}{d_0}\right) + \left(\frac{L}{2} \times \frac{d_3}{d_1}\right)$$

$$F_{4Z} = \frac{L}{4} + \left(\frac{L}{2} \times \frac{d_2}{d_0}\right) + \left(\frac{L}{2} \times \frac{d_3}{d_1}\right)$$

SIDE MOUNTED

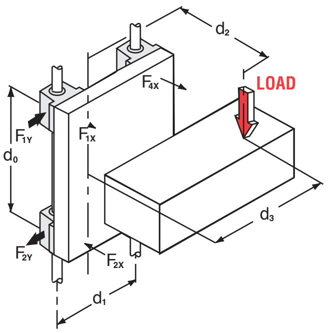


$$F_{1Y} = F_{4Y} = \left(\frac{L}{2} \times \frac{d_3}{d_1}\right)$$

$$F_{1Z} = F_{4Z} = \frac{L}{4} + \left(\frac{L}{2} \times \frac{d_2}{d_0}\right)$$

$$F_{2Z} = F_{3Z} = \frac{L}{4} - \left(\frac{L}{2} \times \frac{d_2}{d_0}\right)$$

VERTICAL MOUNTED



$$F_{1X} = F_{4X} = \left(\frac{L}{2} \times \frac{d_2}{d_0}\right)$$

$$F_{1Y} = F_{4Y} = \left(\frac{L}{2} \times \frac{d_3}{d_0}\right)$$

$$F_{1X} + F_{4Y} = F_{2X} + F_{3X}$$

$$F_{1Y} + F_{4Y} = F_{2Y} + F_{3Y}$$

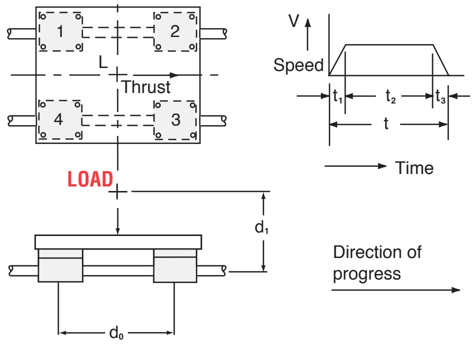
ACCELERATION FORCES

Use the equation in the following figure to determine the additional forces developed due to acceleration.

If impact or impulse loads are anticipated, these forces must also be considered when selecting the appropriate bearing size. **(SEE FIG. 11)**

FIG.11

AT THE TIME OF ACCELERATION AND SLOW DOWN.



At the time acceleration starts:

$$F_1 = F_4 = \frac{L}{4}\left(1 + \frac{2\,V_1 \times d_1}{g \times t_1 \times d_0}\right)$$

$$F_2 = F_3 = \frac{L}{4}\left(1 - \frac{2\,V_1 \times d_1}{g \times t_1 \times d_0}\right)$$

At the time it slows down:

$$F_1 = F_4 = \frac{L}{4}\left(1 - \frac{2\,V_1 \times d_1}{g \times t_3 \times d_0}\right)$$

$$F_2 = F_3 = \frac{L}{4}\left(1 + \frac{2\,V_1 \times d_1}{g \times t_3 \times d_0}\right)$$

At constant velocity:

$$F_1 = F_2 = F_3 = F_4 = \frac{1}{4}L$$

Gravitational acceleration:

$g = 384$ in./sec^2 = 9.8 m/sec^2

SHAFT DEFLECTION

Shaft deflection should be considered when choosing the proper bearing and shaft diameter for end-supported systems. Deflection is directly related to the diameter of the shaft, the unsupported length of the shaft, and the type of shaft end mounting that is used.

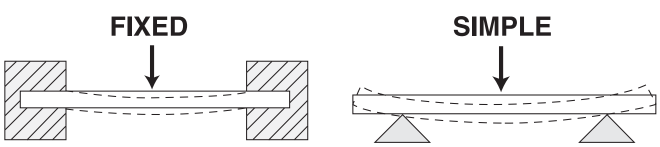
Typical Shaft End Mounting. **(SEE FIG. 12)**

"Simple" - the end allows some of the shaft deflection slope through the fastening point.

"Fixed" - the ends are constrained from deflection.

NOTE: Fixed end mounting can be accomplished by capturing the shaft end with a length of engagement equal to or greater than 1 1/2 times the shaft diameter.

FIG.12



DEFLECTION CALCULATION

Use the formula:

$$D = N \times W \times L^3$$

WHERE:

N = value from fig.13

W = load in pounds

L = length (in inches) of unsupported shaft section

CALCULATE MISALIGNMENT ANGLE

PowerTrax™ linear bearings allow for 1/2 degree misalignment. To determine the amount of misalignment due to shaft deflection use the formula:

$$\theta = \sin^{-1} (D/L)$$

WHERE:

θ = angle in degrees

D = shaft deflection

L = length (in inches) of unsupported shaft selection.

If misalignment is greater than 1/2 degree, then:

- Reduce the Length of the shaft.
- Use a larger shaft diameter.

FIG.13

"N" VALUE FOR NOOK SHAFTS		
SHAFT DIAMETER (in.)	SIMPLE	FIXED
1/4	3620×10^{-9}	905×10^{-9}
3/8	715×10^{-9}	179×10^{-9}
1/2	226×10^{-9}	56.6×10^{-9}
3/4	44.7×10^{-9}	11.2×10^{-9}
1	14.1×10^{-9}	3.54×10^{-9}
1-1/2	2.79×10^{-9}	$.698 \times 10^{-9}$
2	0.866×10^{-9}	$.0220 \times 10^{-9}$
3	0.168×10^{-9}	$.432 \times 10^{-10}$
4	0.052×10^{-9}	$.136 \times 10^{-10}$

APPLICATION EXAMPLES

Application #1 – PACKAGING LINE

An appliance manufacturer needs to move products in boxes so that they can be presented to a transfer conveyor after final assembly.

Specifications:

- The boxes weigh 200 pounds
- The unit reciprocates 8 times per minute
- 4.5 inch stroke
- 365 days per year, ten year design life.
- Slightly corrosive environment

What is the proper size EXCEL™ Bearing which will satisfy this application?

ANALYSIS:

Configuration: There is enough space available for four linear bearings. The system will use stainless steel shafting with a hardness of Rc 55. The load can be centered between four standard Excel™ linear bearings

Travel Life:
4.5 in./stroke x 8 strokes/min. x 60 min./hr x 24 hrs/day x 365 days/year x 10 years = 189,000,000 inches.

Load-Life Ratio Factor (R_L): Based on the computed travel life and the load-life curve R_L = .22.

Shaft Hardness Ratio Factor (R_h):
For PowerTrax™ HG Stainless shafting with a hardness of Rc 55, R_h = .70.

Applied Load (L_a): Per bearing, L_a = 200/4 = 50 lbs.

Equivalent Load (L_e): Substituting in the load formula and solving for L_e = 50 / (.22 x .70) = 325 pounds

SELECTION:

From the EXCEL™ Bearing load tables, the smallest bearing which exceeds this load rating is the 3/4 inch bearing. However, if the application is such that the bearing could be oriented for maximum capacity, then the 5/8 inch bearing could be used.

The Parts List Is:

4 XLEC12 EXCEL™ Linear bearings

2 PowerTrax™ HG Stainless shafting, 9.25 inch minimum length

2 PowerTrax™ NSB-12 End supports