ABOUT BALL SCREWS

Efficiency Expressed as a percentage and is the ability of a ball screw assembly to convert torque to thrust with minimal mechanical loss. Rockford Ball Screws operate in excess of 90% efficiency.

Dynamic Load The maximum thrust load under which a ball screw assembly will achieve a minimum of 1,000,000 revolutions before first signs of fatigue are present.

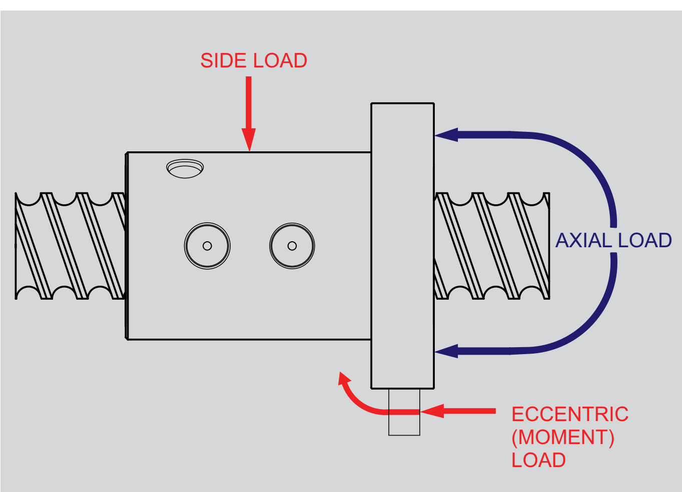
Static Load The maximum non-operating load capacity above which permanent damage of the ball track occurs.

Tension Load A load that tends to stretch the ball screw. This is the preferred mode of attaching the load since column loading limitations would not effect the screw.

Compression Load A load which would tend to compress or buckle the screw shaft. Use column load calculations to determine safe compression loads.

Axial Loading The recommended method of attaching the load to the ballnut. This load should be parallel to the centerline of the screw shaft and equally distributed around the mounting surface.

Eccentric (Moment Loading) A load tending to cock the ballnut on the screw and therefore reducing the rated life.



Side Loading (Radial Loading) A load that is applied perpendicular to the screw shaft. This type of loading will also reduce the rated life of the ball screw assembly.

Ball Screw Life (Life Expectancy) Expressed as total accumulated revolutions under a constant rated thrust load (with proper lubrication and clean environment) before first evidence of fatigue develops (1,000,000 revolutions under stated rated loads). Ball screw life is rated similar to ball bearings (L10). The L10 life rating states that 90% of a similar group of screws will achieve this life. Although 10% will not achieve the life, 50% could exceed life by 5 times.

Applied Dynamic Loading Each unique application needs to be evaluated such that ALL force components are realized and accounted for. The force components might include: weight of the sliding mechanism (if vertical), weight of the sliding mechanism multiplied by the coefficient of sliding friction (if horizontal), any direct forces resisting the linear motion (such as tool cutting loads), and any other applicable force components.

$$P = W\int * \mu + F\rho$$

P = Applied Dynamic Load (N)
W∫ = Weight of Sliding Load (N)
μ = Coefficient of sliding friction (=1 if load orientation is vertical)
Fp = Force component pushing directly against the sliding mechanism (N)

Coefficient of sliding friction for non-vertical loading applications

Steel on Steel	**~.58**
Steel on Steel (greased)	**~.15**
Aluminum on Steel	**~.45**
Gibb Ways	**~.50**
Dove Tail Slides	**~.20**
Linear Bearing (Ball Bushings)	**<.001**

Frictional coefficients are included for reference purposes only and may vary in accordance with actual operating conditions.

Equivalent Load This calculation is used in applications where the load is not constant throughout the entire stroke. This equivalent load can be used in life calculations. In cases where there is only minor variation in loading, use greatest load for conservative life calculation. Please note that the drive torques and horsepower requirements should always be based on the greatest thrust load encountered.

$$P_e = \sqrt[3]{\frac{\%_1(P_1)^3 + \%_2(P_2)^3 + \%_3(P_3)^3 + \%_n(P_n)^3}{100}}$$

Pe = Equivalent Load (N)
Pn = Each Increment at Different Load (N)
%n = Percentage of stroke at load increment

Example: **2000 N load for 25% of stroke**
3300 N load for 50% of stroke
900 N load for 25% of stroke

$$Pe = \sqrt[3]{\frac{25\,(2000)^3 + 50\,(3300)^3 + 25\,(900)^3}{100}}$$

Equivalent Load (Pe) = 2720 N

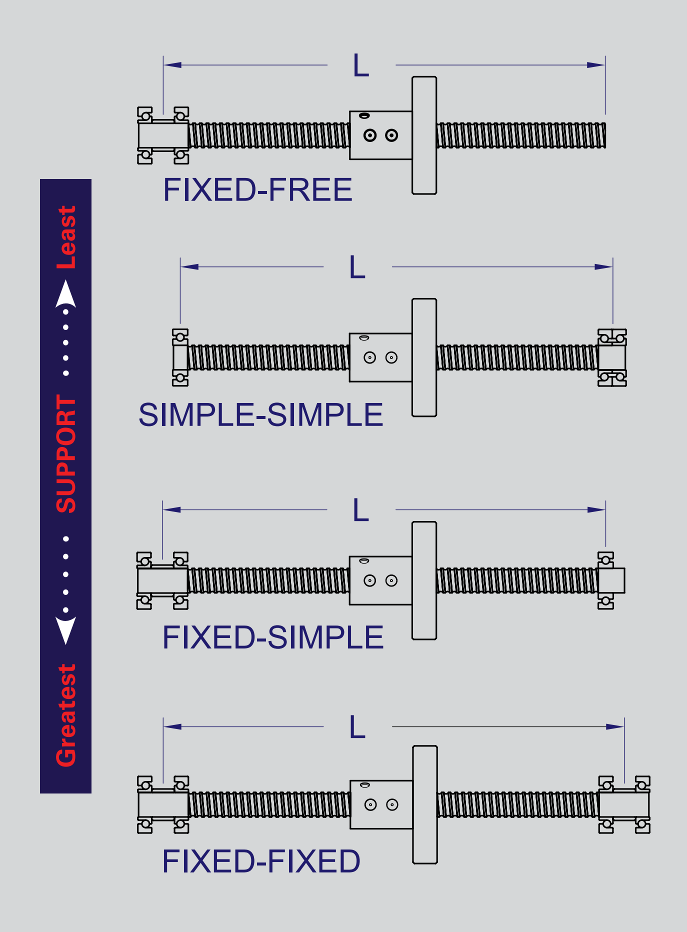
Life At Loads (Other than Rated) Based on the inverse cube ratio in that by operating at 1/2 the rated load you will get 8 times the life or operating at twice the rated load you will get 1/8 the life.

$$(\text{Rated Load} / \text{Actual Load})^3 * 10^6 = \text{LIFE ASSEMBLY UNDER ACTUAL LOAD}$$

Design Life Objective Design Life Objective is the distance that a ball screw will travel during the desired life of the machine. Generally it is ultimately stated in terms of years of life but we need to compare total revolutions to calculated life.

Length of stroke	= 150 mm
Screw Lead	= 10mm/rev
Cycle rate of machine	= 20 Strokes/hr.
Hours of operation/day	= 16 hours
Number of working days per year	= 250 days
Number of years machine is designed for	= 5 years
(150 / 10) * 20 * 16 * 250 * 5	= 6,000,000 revolutions of life

End Fixity End Fixity (Bearing Mount Support Configuration) refers to the method by which the ends of the screws are supported. The end fixity basically describes the bearing configuration being used to support the rotational axis of the screw. The end fixity combinations are determined as a result of critical speed, column loading and system stiffness calculations. There are three basic end fixity styles that can be used in four combinations. The ends styles are “free” (no support), “Simple” (single point support) and “Fixed” (spaced support points).



Critical Speed Critical Speed is the theoretical linear velocity (rpm) which excites the natural frequency of the screw. As the speed of the screw approaches the natural frequency (critical speed), the screw shaft begins to resonate which leads to excessive vibration. The resulting resonance can occur regardless of whether the screw or nut rotates or regardless of screw orientation. R/B/S recommends limiting the maximum RPM to 80% of the calculated critical speed value.

$$C_s = \frac{F_e * 1.2 * 10^8 * D_{min} * F_s}{L^2}$$

Cs = Critical Speed (rpm)
Dmin = Minor Diameter (root) of Screw (mm)
L = Distance between bearing supports (mm)
Fe = End Fixity Variable
= .36 for Fixed-Free Support Configuration
= 1.00 for Simple-Simple Configuration
= 1.47 for Fixed-Simple Configuration
= 2.23 for Fixed-Fixed Configuration
Fs = Factor of Safety (80% recommended)

Speed Limit of Nut is rotational speed limit due to the critical ball velocity within the ball nut for very short periods of time. Exceeding this value can have a detrimental effect on the life of the ball screw assembly.

n < 50000 / Dnom
n = rotational speed (rpm)
Dnom = screw shaft nominal diameter (mm)

Column Load Strength Column Load Strength is the ability of the screw shaft to withstand compressive forces. The fundamental limit occurs when a compressive load exceeds the elastic stability of the screw shaft. Exceeding the column load will result in bending and buckling of the screw. This mode of failure can only occur when the screw shaft is in compression and never in tension. R/B/S recommends limiting the maximum compressive load to 80% of the calculated column load strength.

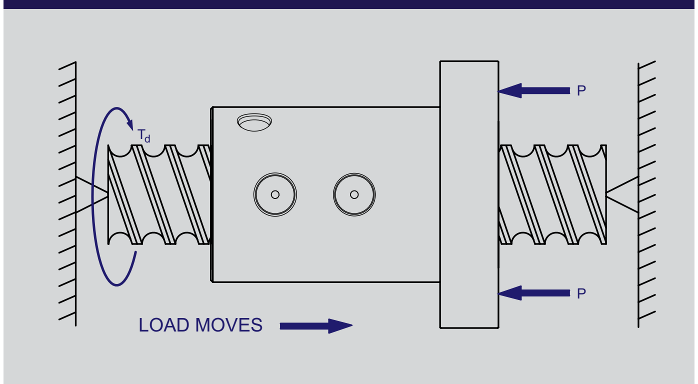
$$P_c = \frac{F_e * 9.69 * 10^4 * D_{\text{min}}^4 * F_s}{L^2}$$

Pc = Maximum Column Load (N)
Dmin = Minor Diameter (root) of Screw (mm)
L = Distance (max.) between load and bearing in compression (mm)
Fe = End Fixity Variable
= .25 for Fixed-Free Support Configuration
= 1.00 for Simple-Simple Configuration
= 2.00 for Fixed-Simple Configuration
= 4.00 for Fixed-Fixed Configuration
Fs = Factor of Safety (80% recommended)

Drive Torque Drive Torque is the amount of torque (Nm) required by the ball screw to move the load. This torque does not take into account any inertial loading required for acceleration.

$$T_d = \frac{S_L * P}{2000 * \pi * E_f}$$

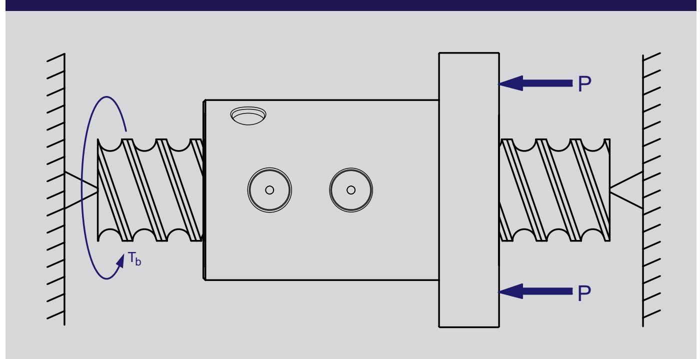
Td = Drive Torque (Nm)
P = Applied Dynamic Load (N) *(see formula page 8)*
SL = Lead of Screw (mm)
Eff = Ball Screw Efficiency (90%)



Back Drive Torque The torque produced through the screw shaft by a thrust load on the ball nut. Ball screws can coast or backdrive due to the high efficiency of the mechanism (90%). If back driving is not acceptable, a method to resist the overturning backdriving systemic torque, such as a brake, will be required to hold the load. If backdriving is desired, the lead of the screw should be at least 1/3 of the screw diameter. Ideally the lead should be equal to the screw diameter. This calculated torque is the minimum amount of braking torque to hold the load in position.

$$T_b = \frac{S_L * P * E_f}{2000 * \pi}$$

Tb = Backdrive Torque (Nm)
P = Applied Dynamic Load (N) *(see formula on page 8)*
SL = Lead of Screw (mm)
Eff = Ball Screw Efficiency (90%)



ABOUT BALL SCREWS

Power Requirements The power (HP) to drive a ball screw assembly is a function of required drive torque and motor R.P.M. Horsepower should be calculated based on the maximum torque required during the stroke or cycle. The highest torques generally are during acceleration due to inertial loading.

$$RPM = \frac{Velocity\ (mm/min)}{Lead\ (mm/rev)}$$

$$Horsepower = \frac{RPM * Drive\ Torque\ (Nm) * 8.85}{63{,}000}$$

Materials and Hardness Most screws and nuts are made from alloy steel and case hardened to Rc 56 minimum.

Screw Straightness Screw straightness is extremely important in minimizing screw vibration. Our ball screw stock is Straight to .25mm/300mm not to exceed .64mm over the entire length. We can hold straightness on machined screws to as little as .05mm/300mm (screw diameter and length dependent).

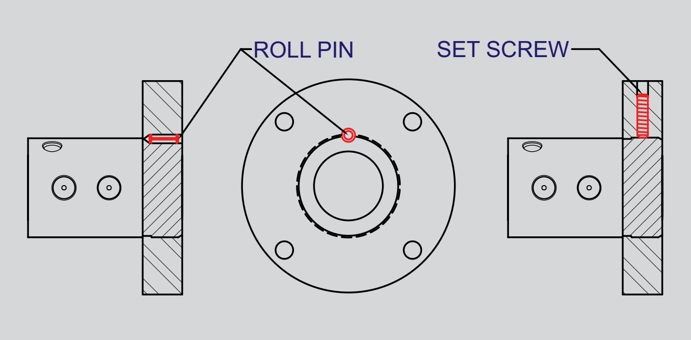
Temperature Range Temperature range for our ball screws is between -20°C (-4°F) and 110°C (230°F) with suitable lubricants.

Lubrication Lubrication is required to achieve optimum life for a ball screw assembly. Ball screws that are not lubricated can experience up to a 90% reduction in calculated life. In general, standard lubrication practices for anti-friction rolling element bearings apply. Grease, oil or dry film lubrication can be used. Many ball nuts are equipped with metric lube port machined into the nut body (see model pages for size information). For models that do not have a factory lube port, contact factory for recommendations regarding application of lubrication.

See page 16 for Rockford Ball Screw Grease. This lubricant is specially formulated for use with ball screws as well as ACME screws and bearing mount assemblies. Rockford Ball Screw Grease is packaged in convenient 14 oz. grease cartridges.

Ball Screw Finish Ball Screw Finish is surface hardened carbon steel. Long term corrosion resistance is accomplished by the rust inhibiting properties of the screw lubricant. Optional black oxide coating can be applied to help prevent corrosion during shipping and brief storage. In applications subject to extreme environments, additional coatings such as nickel, hard chrome, zinc, or others can be applied. Contact Rockford Ball Screw for detailed specifications.

Wiper Kits Wiper kits are standard for all metric ball screw models and come pre-installed. The molded wiper is designed to keep large particulates from entering the ball nut. However for harsh environments, the use of boots or bellows to enclose the screw is recommended. Contact Rockford Ball Screw for further information on enclosures.



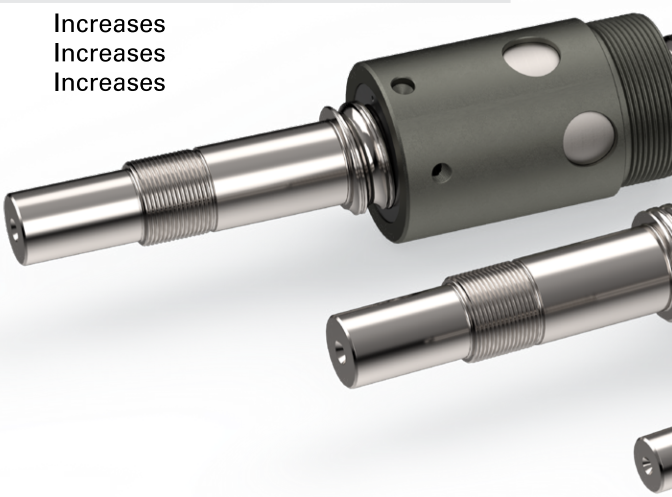
Mounting Flanges If a mounting flange is used instead of the standard v-thread on the ball nut body, it must be permanently attached to prevent disengagement during operation. The two standard methods of retaining the flange is pinning and retaining with a set screw. Commercial thread locking adhesives may also be used (light loads only). It is always recommended that the flange pinning be performed at the factory to assure no metal chips are present after drilling.

Custom precision end machining is available for any specification.

Machined Ends Rockford Ball Screw offers full service machining capabilities to supply screw assemblies that are ready for installation. We offer standard end machining that can accommodate our line of bearing mounts or we can machine ends to your specifications. See pages 36-45 for our standard end machining designs. Screws can also be supplied cut to length. However, it is recommended to have the screw ends factory annealed to assist subsequent machining.

EFFECT OF CHANGE IN PARAMETER

INCREASE IN	EFFECTS	HOW
Screw Length	Critical Speed Column Load	Decreases Decreases
Screw Diameter	Critical Speed Inertia Stiffness Spring Rate Load Capacity Column Load	Increases Increases Increases Increases Increases Increases
Lead	Torque Input Load Capacity Positioning Accuracy Angular Velocity Ball Diameter	Increases Increases Decreases Decreases Increases
Angular Velocity	Critical Speed	Decreases
Mounting Rigidity	Critical Speed System Stiffness	Increases Increases
Load	Life	Decreases
Nut Length (7 1⁄2 Turn Max)	Load Capacity Stiffness	Increases Increases
Number of Balls	System Stiffness Load Capacity	Increases Increases
Preload	Positioning Accuracy System Stiffness Drag-Torque	Increases Increases Increases
Ball Diameter	Life Stiffness Load Capacity	Increases Increases Increases



INVENTORY

Rockford Ball Screw has been manufacturing ball screws, ACME screws and linear motion components since 1973. We pride ourselves in being able to respond to our customers' needs by maintaining one of the largest inventories of products.

We stock in excess of 60 ball screw models, over 25 ACME screws sizes, many types of bearing mounts and other linear motion products. Many products are stocked in a variety of materials such as high and low carbon alloy steels and various grades of stainless steel.

We are equipped to supply your ball and ACME screw requirements with second to none service and delivery times. In addition to our "Standard" inventory lines, we take pride in our specialty and custom designs.

Call us today and see for yourself what "service" really means.

R/B/S MULTI-PURPOSE SYNTHETIC GREASE

AVAILABLE IN 14 OZ. CARTRIDGES

NOTE: To achieve optimal grease performance, it is recommended that the machine components should be kept in careful alignment, the operating environment should be kept clean, and the assembly should be periodically inspected for proper lubrication quantity and integrity.

Advantages Proper lubrication along with reducing/eliminating foreign contamination are essential for preventing premature catastrophic failure. The R/B/S multi-purpose PTFE fortified synthetic grease has been specifically formulated with extreme pressure and anti-wear additives to reduce rolling element friction, wear, and provide noise damping characteristics. The excellent mechanical stability allows for compatibility with ferrous metals, non-ferrous metals, and most engineering plastics.

Consult the factory for specific material interactions. R/B/S recommends this grease be used for ballscrew, ACME screws, bearing mount, and other applications requiring excellent hydrodynamic lubrication.

Data Multi-Purpose Grease Specifications:

NLGI Grade:	2
Temperature Range:	-40°C (-40°F) and 135°C (275°F)
Base Fluid Viscosity (cSt):	75 @ 40ºC 12 @ 100ºC
Worked Penetration: (ASTM D1403)	291

Ball Screw Selection Example:

Specification:
Equipment: Transfer Table
Screw Orientation: **Horizontal**
Load Supported on Dove Tail Ways: **.20** Coefficient of friction
Load is **16000** N Max (combined weight of product and table)
Stroke Length: **1000** mm
Over Travel (per side): **10** mm
Travel rate: **7500** mm per minute (Max.)
Input RPM: **1600**
Duty Cycle: **20** cycles per hour, **16** hours per day, **250** days per year
Required Life: **5** years

Given Specification in GOLD
Resultant Calculation in RED
Catalog Product Data in PURPLE

Specifications to be used to select proper ball screw assembly

Steps:

1 Determine Required Life (mm):

1000 mm/stroke * 2 strokes/cycle * **20** cycles/hr * **16** hrs/day * **250** days/year * **5** years = **800,000,000** mm

2 Determine Thrust Load on Ball Screw – Multiply the thrust load by the coefficient of sliding friction (for horizontal application):

16000 N * **.20** Coefficient of Friction = **3200** N
Use this load for life calculations. *(If load varies during the stroke or cycle, an equivalent load calculation can be utilized page 9)*

3 Determine Lead of the Screw:

Using RPM formula (page 12):

$$RPM = \frac{Velocity\ (mm/min)}{Lead\ (mm/rev)}$$

$$\frac{7{,}500\ (mm/min)}{1{,}600\ rpm} = 4.7\ mm/rev\ (lead)$$

Select 5mm which is the next closest lead.

$$\frac{800{,}000{,}000\ mm}{5\ mm/rev} = 160{,}000{,}000\ rev$$

4 Determine Required Ball Screw Dynamic Axial Loading to Achieve Required Life:

Using formula on page 9, input the **3200** N thrust load (Or equivalent load) and the required life.

The result is the minimum rated load for a ball screw to achieve the required life.

$$\left(\frac{Rated\ Load\ (P_r)}{Actual\ Load\ (P_t)}\right)^3 * 1{,}000{,}000\ rev = Life\ of\ assembly\ under\ actual\ load$$

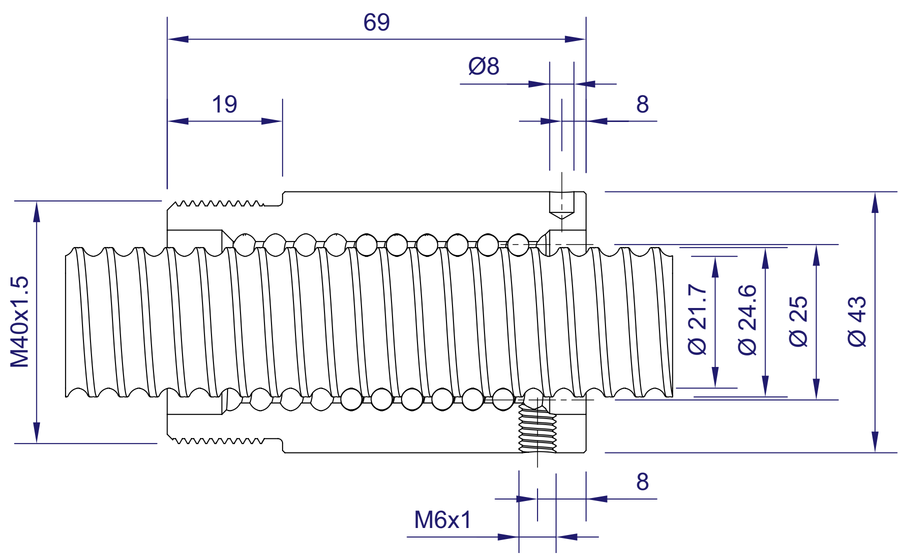
$$\left(\frac{P_r}{3{,}200\ N}\right)^3 * 1{,}000{,}000\ rev = 160{,}000{,}000\ rev$$

$$\left(\frac{P_r^3}{3{,}200^3}\right) = \frac{160{,}000{,}000\ rev}{1{,}000{,}000\ rev} \rightarrow P_r = \sqrt[3]{160 * 3{,}200^3} = 17{,}372\ N$$

USE THIS QUICK REFERENCE CHART TO SELECT APPROPRIATE BALL SCREW MODEL

SCREW DIA. X LEAD	SCREW RATED LOAD (kN)	SCREW MINOR DIA.	CATALOG PAGE NUMBER
M16x5	7.6	12.7	26
M20x5	14	16.7	28
M25x5	19	21.7	27
M25x10	23.5	20.5	26
M32x5	22	28.7	28
M32x10	27.1	27.8	29
M40x5	24.3	36.7	30
M40x10	61.5	37	31

Ball Screw Selection:
Load Rating: Load Rating: Smallest diameter screw with **17,372** N (min.) operating load and a **5** mm lead is the M25x5 (page 27)



5 Calculate Length Between Bearing Supports:
Length between bearings = Stroke length + Ball Nut length + Desired over-travel

1000 mm stroke + **69** mm nut length (page 27) + **20** mm over-travel = **1089** mm between bearings
(use this length for column load and critical speed calculations)

6 Calculate End Fixity Based on Critical Speed Limits (page 9-10):
Using formula for Critical Speed, rearrange to solve for Fe (End Fixity Variable)

$$C_s = \frac{F_e * 1.2 * 10^8 * D_{min} * F_s}{L^2}$$

Cs = Critical Speed = **1600** rpm
Dmin = Minor Diameter (root) of Screw = **21.7** mm
L = Distance between bearing supports = **1089** mm
Fe = End Fixity Variable
= .36 for Fixed-Free Support Configuration
= 1.00 for Simple-Simple Configuration
= 1.47 for Fixed-Simple Configuration
= 2.23 for Fixed-Fixed Configuration
Fs = Factor of Safety (80% recommended)

Equations below will solve for the minimum end fixity factor based on a speed of 1600 rpm.

$$1{,}600\ rpm = \frac{F_e * 1.2 * 10^8 * 21.7 * .8}{1{,}089^2}$$

$$F_{e(\min)} = \frac{1{,}600 * 1{,}089^2}{1.2 * 10^8 * 21.7 * .8} = 0.91$$

Select End Fixity Factor larger than 0.91

Thus a Simple-Simple (Fe = 1.00) is the proper selection

7 Actual Calculated Critical Speed:

This calculated critical speed is based on the Simple-Simple end fixity arrangement. It is the maximum safe linear speed with this mounting arrangement, screw model and between bearing supports distance. If greater speed is required, a Fixed-Simple or Fixed-Fixed arrangement can be used and recalculate maximum speed accordingly.

$$C_s = \frac{1.00 * 1.2 * 10^8 * 21.7 * .8}{1{,}089^2} = 1{,}756\ rpm$$

(maximum attainable safe linear speed)

8 Calculate Critical Ball Speed (DN) (page 10):

n < 50000 / Dnom

n < 50000 / 25 ⟶ n < 2000 rpm

$$n_{max} = \frac{50,000}{D_{nom}}$$

$$n_{max} = \frac{50,000}{25} = 2,000\ rpm$$

9 Calculate Column Load Limit (page 10):

This calculated column load is the maximum safe compression load allowable based on mounting arrangement, screw model and distance between bearings. In this example the calculated column loading should be greater than **3200** N. (Step #2).

$$P_c = \frac{F_e * 9.69 * 10^4 * D_{\min}^4 * F_s}{L^2}$$

Pc = Maximum Column Load (N)

Dmin = Minor Diameter (root) of Screw = 21.7 mm

L = Distance (max.) between load and bearing in compression = **1089** mm

Fe = End Fixity Variable

= .25 for Fixed-Free Support Configuration

= 1.00 for Simple-Simple Configuration

= 2.00 for Fixed-Simple Configuration

= 4.00 for Fixed-Fixed Configuration

Fs = Factor of Safety (80% recommended)

$$P_c = \frac{1.00 * 9.69 * 10^4 * 21.7^4 * .8}{1,089^2} = 14,500\ N\ max$$

10 Calculate Drive Torque (page 11):

$$T_d = \frac{S_L * P}{2000 * \pi * E_f}$$

Td = Drive Torque (Nm)

P = Applied Dynamic Thrust Load = **3200** N

SL = Lead of Screw = **5** mm/rev

Eff = Ball Screw Efficiency (**90%**)

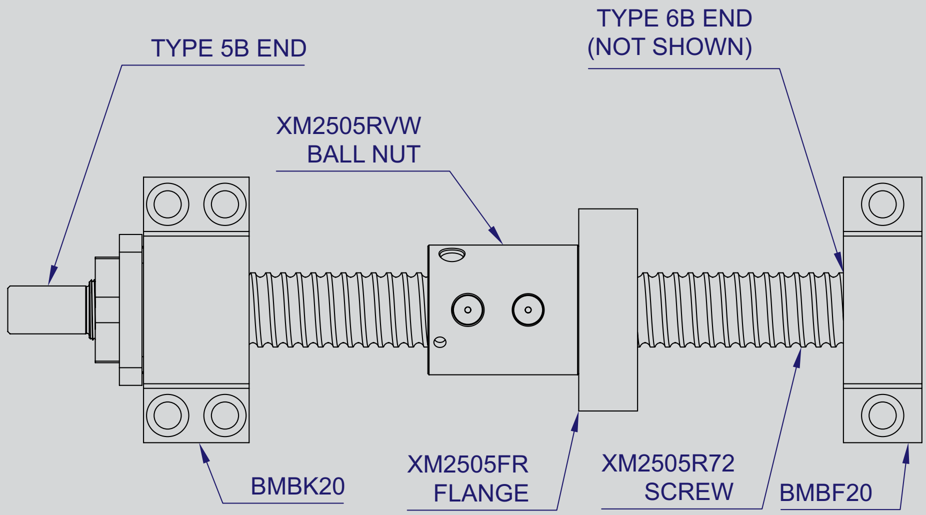
$$\longrightarrow \frac{5 * 3,200}{2000 * \pi * .9} = 2.8\ Nm\ torque\ at\ constant\ velocity$$

11 Calculate H.P. Required at Constant Velocity (page 12):

$$Horsepower = \frac{RPM * Drive\ Torque\ (in.lbs) * 8.85}{63{,}000} \longrightarrow \frac{1600 * 2.8 * 8.85}{63{,}000} = 0.63\ HP\ min$$

12 Specifying Proper Ball Screw Assembly (page 27):

Screw Overall Length = **1089** between bearings + **80 (Type 5B) + 16 (Type 6B)** = **1185** mm OAL



Model Size: **XM2505** Ballnut #: **XM2505RVW** Mounting Flange #: **XM2505FR**

Bearing Mount Part #: **BMBF20** (compact simple radial support) non-drive end

BMBK20 (compact simple angular support) drive end

Ball Screw Machined Ends: **Type 5B** one end and **Type 6B** other end

13 Go to website to get 2D & 3D downloadable drawings: www.rockfordballscrew.com