Engineering

Engineering Guidelines for Inch Series Ball Screws

Selecting a Ball Screw Assembly for Your Application — Inch Series

A ball screw assembly is a mechanical device for translating rotational motion to linear motion. As well as being able to apply or withstand high thrust loads, they can do so with minimum internal friction. They are made to close tolerances and are therefore suitable for use in situations in which high precision is necessary. The selection of the correct ball screw assembly for a specific application is an iterative process to determine the smallest envelope and most cost-effective solution. Below is a list of the most common (but not complete) design considerations used to select a ball screw assembly.

- Compression or Tension Load
- Linear Velocity
- Positional Accuracy and Repeatability
- Required Life Expectancy
- Mounting Configuration
- Dimensional Constraints
- Input Power Requirements
- Environmental Condition

At a minimum, the design load, linear velocity, and positional accuracy should be the known inputs and are used to calculate the diameter, lead, and load capacity of the ball screw assembly. Individual ball screw components are then selected based on life, dimensional constraints, mounting configuration, and environmental conditions.

The following procedure will take you through the most common application-based selection of a ball screw assembly. As no two applications are the same, so the determination process is never the same.

1. Determine the required positional accuracy and repeatability that your application requires (page 143). Backlash is the linear independent motion between the ball screw and the ball nut and can be controlled by preloading the ball nut (page 144). The manufacturing process, rolled screws versus ground screws, dictates the accuracy (page 144).
2. Determine how you plan to mount the ball screw assembly into your machine (see page 146). The configuration of the end supports and the travel distance (Max L) will dictate the load and speed limitations of the ball screw.
3. A ball nut in tension can handle loads up to the rated capacity of the nut. For a ball nut in compression, calculate the Permissible Compression Loading (page 142) or use the Compression Loading Chart (page 149) to select a ball screw diameter that meets or exceeds your design load.
4. Calculate the lead of the ball screw that will produce the speed requirement (page 140).
5. The ball nut life can then be calculated using the Dynamic Load Rating (C_{am}) provided in the catalog detail pages or use the Life Expectancy Charts (page 148).
6. Every ball screw has a rotation speed limit, which is the point of excessive vibration/harmonics in the screw. The critical speed is dependent on the end support configuration. Calculate the Critical Screw Speed of the chosen ball screw (page 142) or use the Acceptable Speed Chart (page 147) to determine the critical speed.
7. If the load, life and speed calculations confirm that the selected ball screw assembly meets or exceeds the design requirements, then proceed to the next step. If not… Larger diameter screws will increase the load capacity and increase the speed rating. Smaller lead screws will decrease the linear speed (assuming constant input motor speed), increase the motor speed (assuming constant linear speed), and decrease the input torque required. Higher lead screws will increase the linear speed (assuming constant input motor speed), decrease the input motor speed (assuming constant linear speed), and increase the input torque required. Repeat steps 3 thru 5 until the correct solution is obtained.
8. Determine how the ball nut will interface into your application. A ball nut flange is the typical method of attaching the ball nut to the load. Threaded ball nuts and cylindrical ball nuts are alternative ways to provide the interface.
9. Additional design considerations and features are also available. Preloaded ball nuts are available to eliminate system backlash and increase stiffness. Wiper kits to protect the assembly from contaminants and to contain lubrication are standard on some units and optional on most others. Bearing supports and end machining are also available as options for most ball screws.
10. The final considerations are system mounting and lubrication. The ball nut should be loaded axially only as any radial loading significantly reduces the performance of the assembly (page 145). The assembly should also be properly aligned with the drive system, bearing supports, and load to achieve optimal performance and life (page 145). The ball screw assembly should never be run without proper lubrication. Many lubricants are available depending on the application and environment (page 145).

Note: Application and customer service support is available to assist in the selection of your ball screw assembly. Please contact your local Thomson representative or the customer support center (1-540-633-3549 — TCS) for any additional assistance.

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Ball Screw Assembly Selection Example:

Inputs:

Load: 30,000 lb. Compression Maximum
10,000 lb. dynamic
Linear Speed: 200 in./min.
Input Speed: 400 rpm
Travel: 85 in.
Life: 2×10^6 inches

1. **Accuracy (pages 143 and 144)**
   No Preload and Standard Rolled (±.004 in./12 in.)

2. **End Supports (page 146)**
   Fixed/Supported

3. **Determine Screw Diameter**
   From Chart (page 149): Ø2.000 in.

   From Equation (page 142): $30{,}000 / .8 = \dfrac{2.0 \times 1.405 \times 10^7 \times d_r^4}{(85)^2}$

   therefore, $d_r = 1.762$ in.

4. **Determine Lead**

   Lead = $\dfrac{200 \text{ in./min.}}{400 \text{ rpm}}$ therefore, Lead = .500 in.

5. **Determine Life**
   From Catalog (page 43): Dynamic Load = 21,306 lbs.

   From Equation (page 141): Life (inches) = $\left[\dfrac{21{,}306}{10{,}000}\right]^3 \times 10^6$

   therefore, Life = 9.7×10^6 inches

   Verified via Chart (page 149)

6. **Determine Critical Speed**
   From Catalog (page 43): Screw Root Diameter is 1.85 in.

   From Equation (page 142): $.8 \times 1.47 \times 4.76 \times 10^6 \times \dfrac{d_r}{l^2}$

   therefore, Speed = 1,433 rpm

   Verified via Chart (page 147)

7. **Design Verification**
   OK per load, speed and life.

8. **Load Interface**
   Flanged connection preferred.

9. **Additional Requirements**
   - Wipers required
   - Bearing Supports required
   - End Machining needed
   - Right Hand Thread
   - Carbon Steel

10. **Mounting and Lubrication**
    System will require motor interface and linear rails for alignment.
    TriGel 450R

Product Selection

Ball Nut: P/N 8122-488-005

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Design Formulas

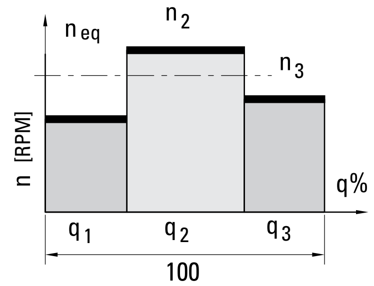
These formulas allow you to calculate a number of important factors which govern the application of Thomson ball screws.

1. Ball Screw Life (L)

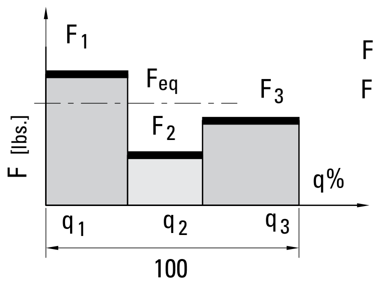
The ball screw assembly's useful life will vary according to load and speed. Life is typically rated at 90% confidence, L10 (which represents time at which 90% of assemblies still perform).

Functional life should be determined by approximating equivalent rotational speed and loading force over typical performance cycles.

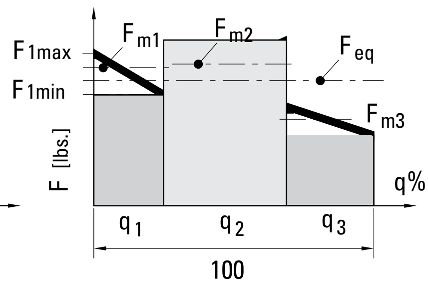
Simple rotational speed profile



Simple loading profile (1)



Simple loading profile (2)



$$n_{eq}\left[\min^{-1}\right] = \sum_{i=1}^{n} n_i \times \frac{q_i}{100}$$

$$F_{eq}\left[\text{lbs.}\right] = \left(\sum_{i=1}^{n} F_i^{\,3} \times \frac{n_i}{n_{eq}} \times \frac{q_i}{100}\right)^{1/3}$$

$$F_{eq}\left[\text{lbs.}\right] = \left(\sum_{i=1}^{n} F_{mi}^{\,3} \times \frac{n_i}{n_{eq}} \times \frac{q_i}{100}\right)^{1/3}$$

Modified Life

$$L_{10}\left[\text{inches}\right] = \left[\frac{C_{am}}{F_{eq}}\right]^3 \times 10^6$$

$$L_{h10}\left[\text{hours}\right] = \frac{L_{10}}{n_{eq} \times 60}$$

Parameters:

n_{eq} = Travel Rate (inches/min)

F_{eq} = equivalent operating load [lbs.]

C_{am} = dynamic load rating [lbs.]
(see product detail pages)
(Based on 1.0 million inches)

2. Rotational Speed Required for a Specific Linear Velocity

$$n = \frac{\text{Travel Rate (in. x min.}^{-1}\text{)}}{\text{Lead (in.)}}$$

n = rpm

3. Machine Service Life

After ball screw life (L) is calculated, apply it to the following formula to determine machine service life.

$$\text{Machine Service Life (in years)} = \frac{L_{h10}\,[\text{hours}]}{(\text{machine operating hours}) \bullet (\text{days/year}) \bullet \left(\dfrac{\text{ball screw operating hours}}{\text{machine operating hours}}\right)}$$

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4. Torque

a. Driving torque: $T_d\ (lb_f\text{-in.}) = \dfrac{F_{eq} \times P}{2\pi e} = 0.177 \times F_{eq} \times P$

b. Backdrive torque: $T_b\ (lb_f\text{-in.}) = \dfrac{F_{eq} \times P \times e}{2\pi} = 0.143 \times F_{eq} \times P$

(conversion of linear to rotational motion)

F_{eq} = Equivalent Operating Load (lb_f)
P = Lead (in.)
e = Efficiency = 0.90
T_d = Driving Torque (lb_f-in.)
T_b = Backdrive Torque (lb_f-in.)
1 lb_f-in. = 0.113 (N•m)

5. Power

$$P_d\ (hp) = \frac{F_{eq} \times P}{(2\pi)\ e} \times \frac{n}{6.3021 \times 10^4} = \frac{F_{eq} \times P \times n}{3.564 \times 10^5}$$

P_d = Power (hp)
n = rpm
1 hp = 746 W

6. Permissible Rotational Speed

The permissible rotational speed depends on two factors: critical screw speed and critical nut speed.

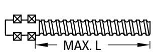
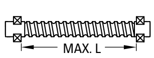
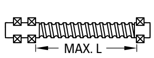
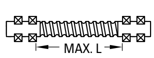
6a. Critical Screw Speed

The critical screw speed is related to the natural frequency of the screw shaft. Exceeding this value may result in excessive vibration. The critical screw speed may be found using the following equations or the chart on page 147.

$$n_c = C_s \times 4.76 \times 10^6 \times \frac{d_r}{l^2}$$

$$n_s = n_c \times S$$

n_c = Critical Speed (rpm)
n_s = Safe Drive Speed
d_r = Root Diameter (in.)
l = Length between Bearing Supports (in.)
S = Safety Factor (0.8 maximum)
C_s = End Fixity Factor

End Fixity Factor - Critical Screw Speed			
End Supports			C_S
A		One end fixed, one end free	0.36
B		Both ends supported	1.00
C		One end fixed, one end supported	1.47
D		Both ends fixed	2.23

6b. Critical Nut Speed

The critical nut speed is related to the velocity of the ball bearings rotating around the screw shaft. Exceeding this value may result in permanent damage to the ball recirculation components. Thomson recommends a maximum DN value of 3000 for standard tube transfer designs with a lead to diameter ratio less than 2/3. Thomson recommends a maximum DN value of 5250 for high speed nuts equipped with deflectors.

$DN = d_0 n$

where
d_0 = nominal shaft diameter (in)
n = rotational speed of shaft (rpm)

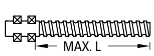
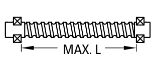
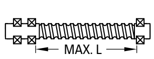
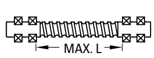
7. Permissible Compression Loading

Exceeding the recommended maximum compression force may result in buckling of the screw shaft.

$$F_c = \frac{C_s \times 1.405 \times 10^7 \times d_r^4}{l^2}$$

$$F_s = F_c \times S$$

F_c = Critical Buckling Force (lbs.)
F_s = Safe Compression Force (lbs.)
d_r = Root Diameter (in.)
l = Max Unsupported Length (in.)
S = Safety Factor (0.8 maximum)
C_s = End Fixity Factor

End Fixity Factor - Permissible Compression Loading			
End Supports			C_S
A		One end fixed, one end free	0.25
B		Both ends supported	1.00
C		One end fixed, one end supported	2.00
D		Both ends fixed	4.00

Engineering Guidelines for Inch Series Ball Screws

Accuracy Classes

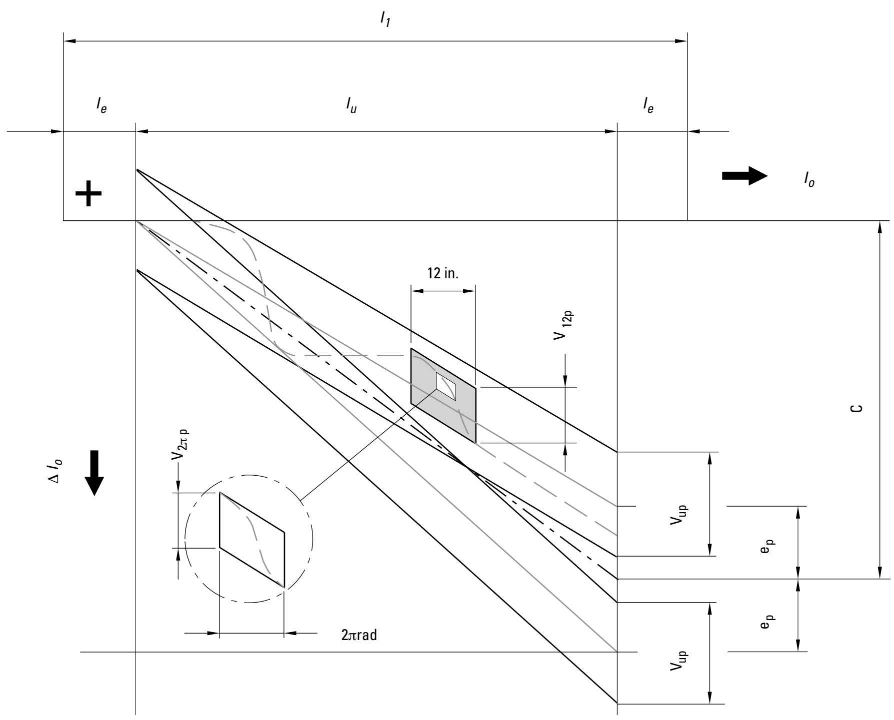
Accuracy is a measure of how closely a motion system will approach a command position. Perfect accuracy, for example, means that advancing a ball nut a precise amount from a given point on the screw always requires exactly the theoretically predicted number of revolutions.

Inch ball screws are produced in two main tolerance classes: Precision and Precision Plus. Precision grade ball screws are used in applications requiring only coarse movement or those utilizing linear feedback for position location. As such, most Precision grade screws are provided with nuts having backlash. Precision Plus grade ball screws are used where repeatable positioning within microns is critical, without the use of a linear feedback device.

Differences between Precision and Precision Plus grades are highlighted in the graph. Precision grade screws allow greater cumulative variation over the useful length of the screw. Precision Plus grade screws contain accumulation of lead error to provide precise positioning over the screw's entire useful length.

Precision Plus Ball Screws

Maximum error over useful length = $e_p + 1/2V_{up} + C$



l_o = nominal travel

l_1 = thread length

l_o = travel deviation

l_u = useful travel

l_e = excess travel

C = travel compensation for useful travel (std. = 0)

e_p = tolerance for actual mean travel deviation (the difference between the maximum and minimum values of the permissible actual mean travel)

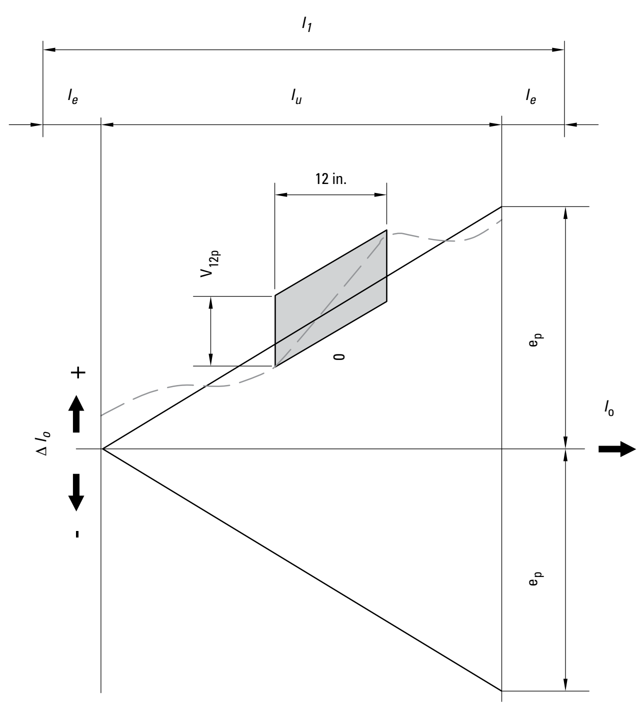
V_{up} = permissible travel variation within useful travel, l_u

V_{12p} = permissible travel deviation within 12 inch travel

$V_{2?p}$ = permissible travel deviation within 1 revolution

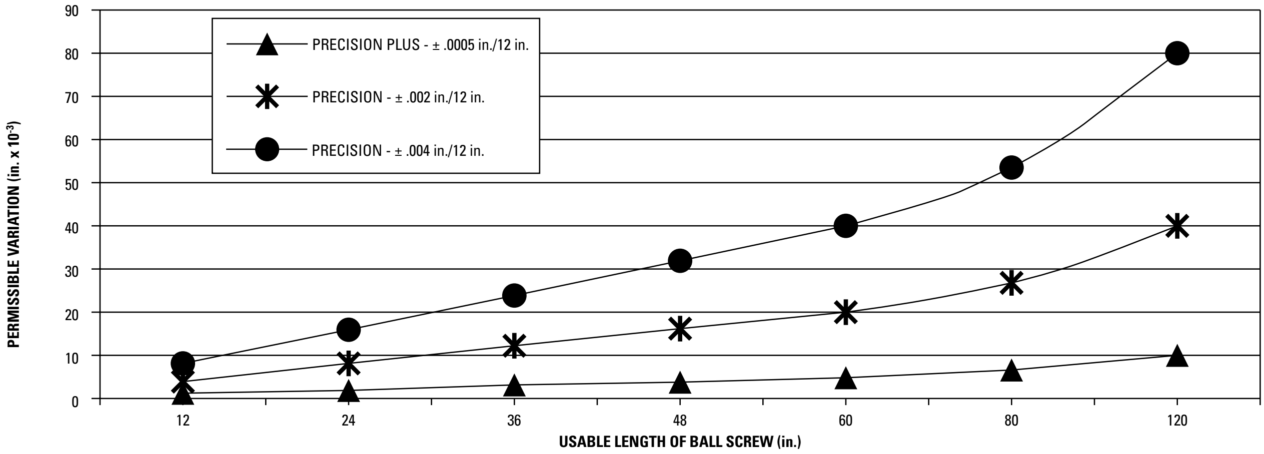
Precision Ball Screws

Maximum error over useful length = e_p



Engineering Guidelines for Inch Series Ball Screws

Permissible Travel Variation Over Usable Length

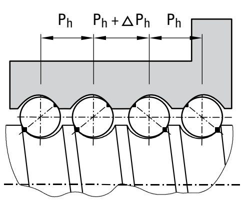


Tolerance Class	Lead Accuracy V_{300p}	Permissible Travel Deviation V_{up} (in. x 10^{-3}) Over Screw Length l_u (in.)							
		l_u =	12	24	36	48	60	80	120
Precision Plus*	±.0005 in./12 in.	V_{up} (in.)	1	2	3	4	5	6.67	10
Precision	±.002 in./12 in.	V_{up} (in.)	4	8	12	16	20	26.7	40
Precision*	±.004 in./12 in.	V_{up} (in.)	8	16	24	32	40	53.3	80

* Standard product tolerances

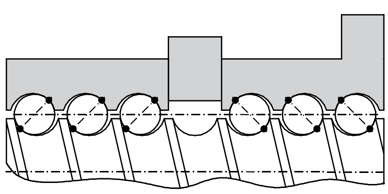
Preload Types

Skip-Lead Preload

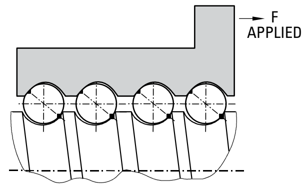


- The lead is offset within the ball nut to provide a precise preload.
- Typically used where both repeatability and high stiffness are required.

Double-Nut Adjustable Preload



- A compression spring is used to axially load two ball nuts against each other.
- Typically used for positioning applications where repeatability is critical.



- Axial play is present between screw and nut (typically .002"-.008" depending on size).
- Typically used for transport or vertical applications.

No Preload

Engineering Guidelines for Inch Series Ball Screws

Lubrication Guidelines

Ball screws must be lubricated to operate properly and achieve the rated life. We recommend using TriGEL-450R or TriGEL-1800RC for lubricating ball screws. Other oils and greases may be applicable but have not been evaluated.

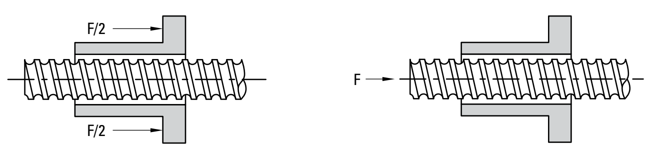
The TriGEL grease can be applied directly to the screw threads near the root of the ball track. Some ball nut sizes are available with threaded lube holes for mounting lubrication fittings. For these ball nuts, the TriGEL grease can be pumped directly into the nut. Please refer to the catalog detail views to verify which ball nuts have the threaded lube holes. It is recommended to use these nuts in conjunction with a wiper kit to contain the lubricant in the body of the nut.

Ball screws may require lubrication frequently depending on both environmental and operating conditions. If the lubricant appears to be dispersed before this point or has become dry or crusted, the maintenance interval should be reduced. Before adding additional grease, wipe the screw clean, removing the old grease and any particulate contamination seen on the screw. If oil is being used, the best results may be obtained by utilizing a continuous-drip type applicator.

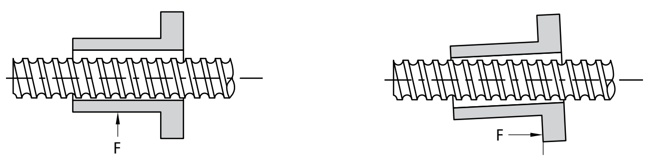
Nut Loading

Axial loading (on nut or screw) is optimal for performance and life.
For applications requiring radial loads, please contact us.

Axial Loading: optimal



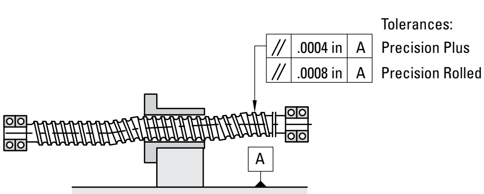
Radial Loading: detrimental*

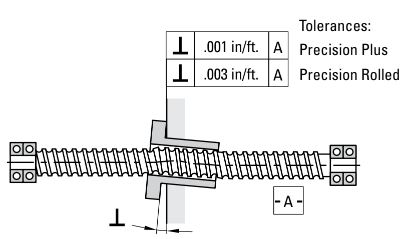


* Minimize radial loading to less than 5% of the axial load.

Nut Mounting

Use the following guidelines to achieve optimal performance





Engineering Guidelines for Inch Series Ball Screws

Bearing Support Reference Drawings (End Fixity)

Critical Speed — That condition where the rotary speed of the assembly sets up harmonic vibrations. (Refer to Figure 1.) These vibrations are the result of shaft diameter, unsupported length, type of bearing support, position of the ball nut in the stroke, how the ball nut is mounted, the shaft or ball nut rpm, etc. (Note: Shaft vibrations may also be caused by a bent screw or faulty installation alignment.) The four end fixity drawings (A, B, C, and D) show the bearing configurations for supporting a rotating shaft. The selection chart for Travel Rate vs. Length on page 147, shows these same configurations at the bottom of the chart and factors in their effect on critical shaft speed for the unsupported screw length.

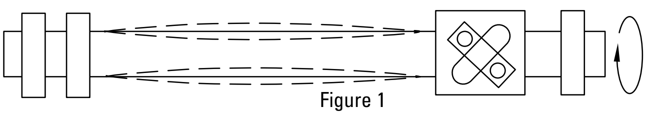
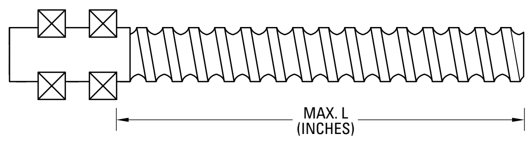


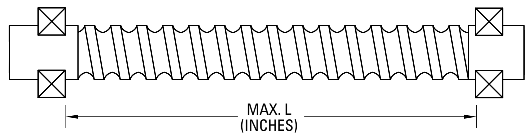
Figure 1

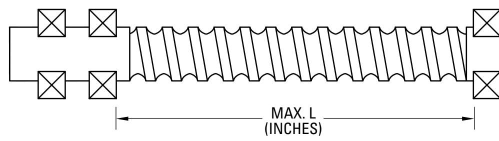
Bearing Support vs. Speed (travel rate or rpm)

A – One end fixed, other end free

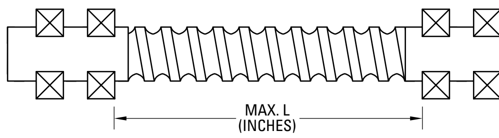


B – Both ends supported





C – One end fixed, other end supported



D – Both ends fixed

Tension Loads — Those loads where the force pulls on the bearing and its support. (Refer to Figure 2.) Where practical, applications should be designed to function with the load in tension to achieve the widest possible selection of screw sizes. Ball screws operating in both tension and compression may be preloaded between the support bearings or mounted per the guidelines under Compression Loads.

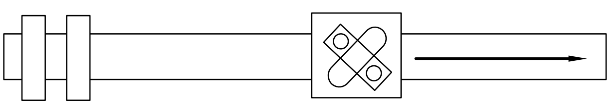


Figure 2

Compression Loads — Those loads where the force pushes on the bearing and its support. (Refer to Figure 3.) Compression loads tend to cause the screw shaft to bend. This normally requires a ball screw with a larger diameter than one for tension loading only. The four end fixity drawings (A, B, C and D) show the bearing configurations for supporting a shaft subject to compression loads. The selection chart for Compression Load vs. Length, on page 149, shows these same configurations at the bottom of the chart and factors in their effect on the unsupported length of the screw for compression loads.

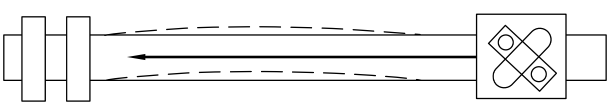
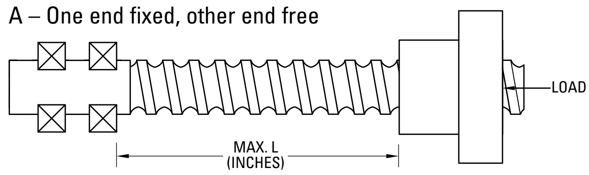


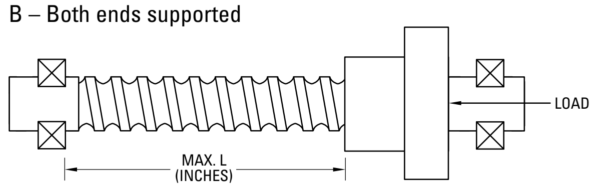
Figure 3

Bearing Support vs. Compression Load on Screws

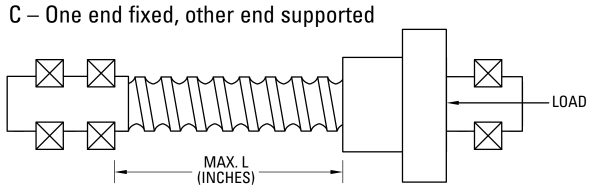
A – One end fixed, other end free



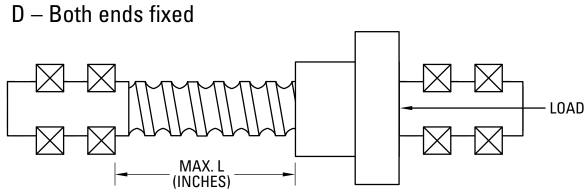
B – Both ends supported



C – One end fixed, other end supported

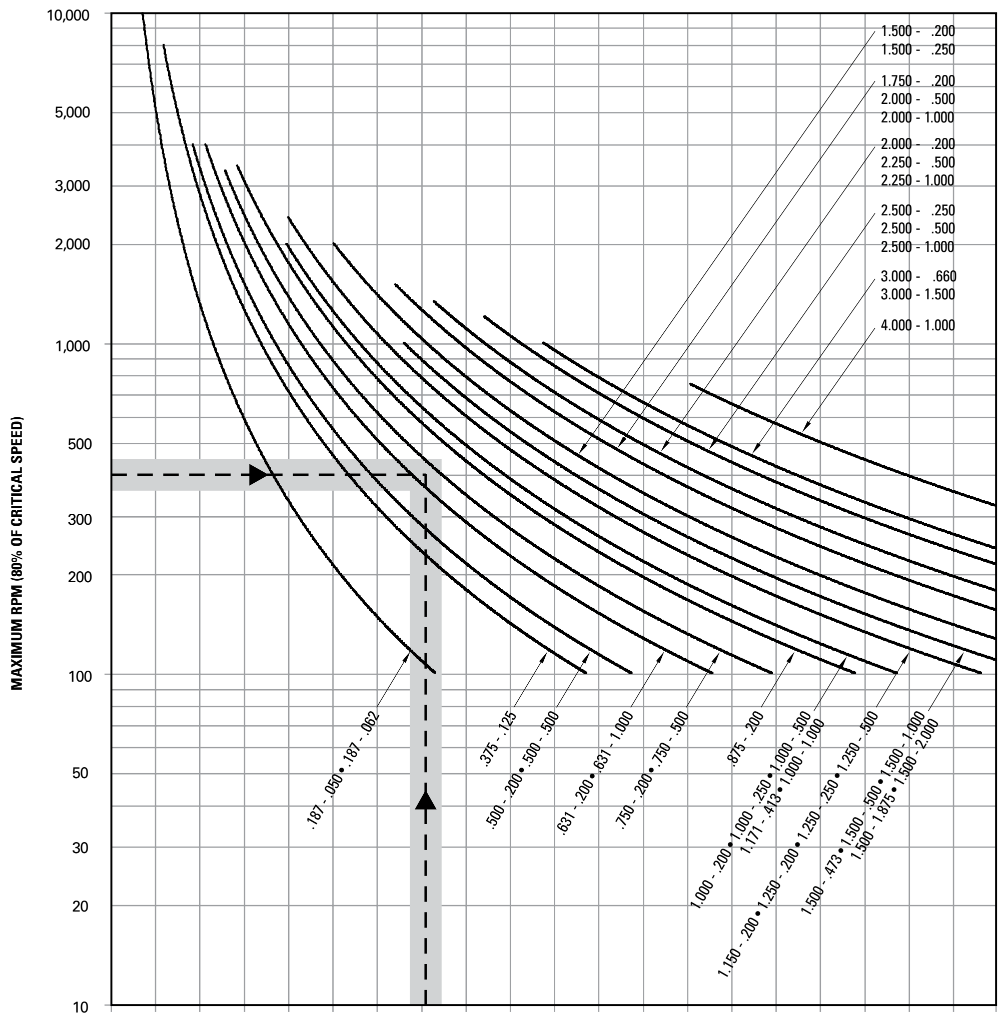


D – Both ends fixed



Engineering Guidelines for Inch Series Ball Screws

Acceptable Speed† vs. Length for Screws



END SUPPORT TYPE

A	One end fixed, other end free (MAX. L)	Inches	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
		mm	152	304	457	609	762	914	1056	1219	1371	1524	1676	1828	1981	2133	2286	2438	2590	2743	2895	3048
B	Both ends supported (MAX. L)	Inches	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
		mm	254	508	762	1016	1270	1524	1778	2032	2286	2540	2794	3048	3302	3556	3810	4064	4318	4572	4826	5080
C	One end fixed, other end supported (MAX. L)	Inches	12	24	36	48	61	73	85	97	109	121	133	145	158	170	182	194	206	218	230	242
		mm	304	609	914	1219	1549	1854	2159	2463	2768	3073	3378	3683	4013	4318	4622	4927	5232	5537	5842	6146
D	Both ends fixed (MAX. L)	Inches	15	30	45	60	75	90	105	119	134	149	164	179	194	209	224	239	254	269	284	298
		mm	381	762	1143	1524	1905	2286	2667	3022	3403	3784	4165	4546	4927	5308	5689	6070	6451	6832	7213	7569

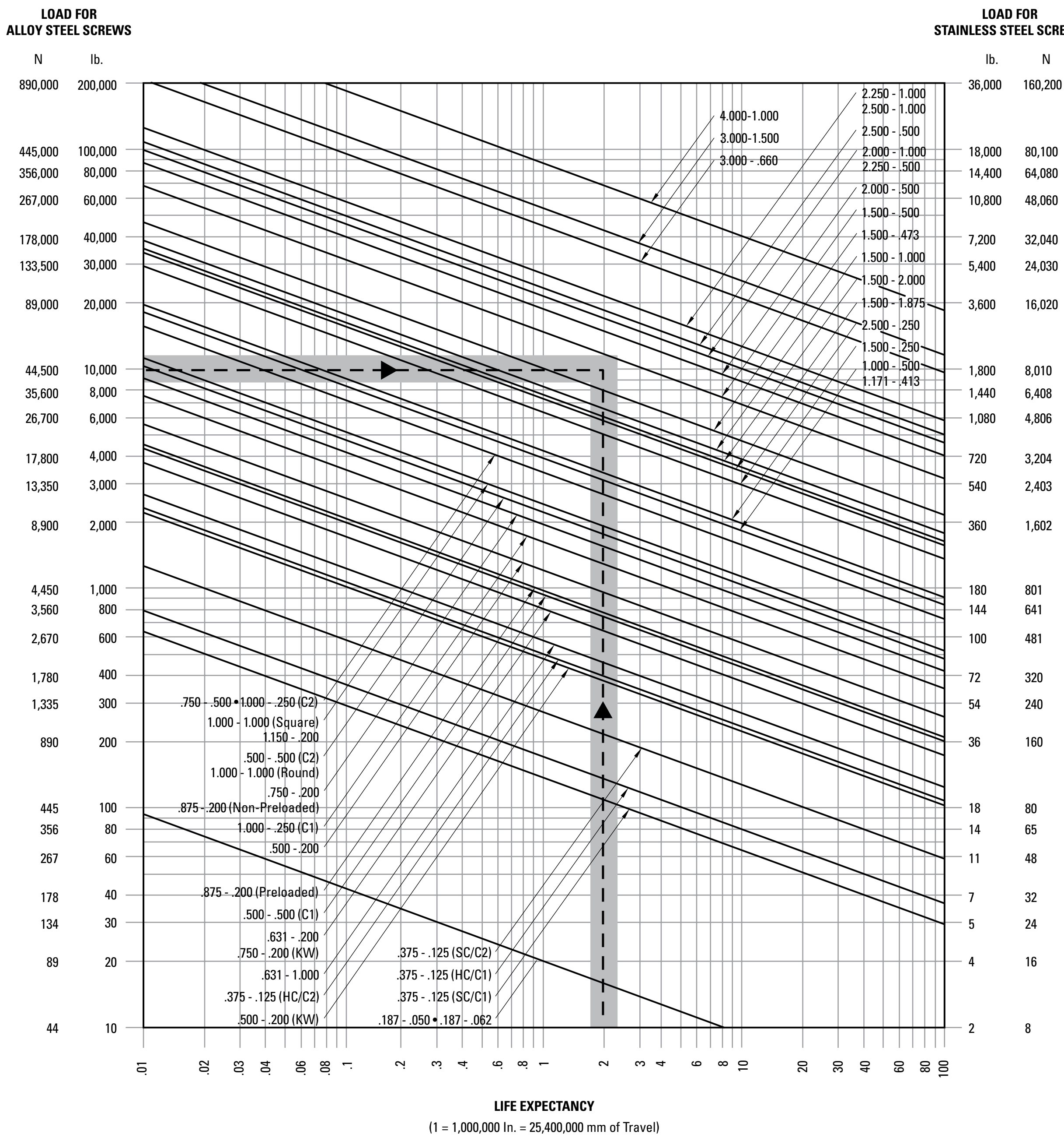
Example: Travel rate of 400 rpm.
Unsupported length of 85 in. (2159mm).
End fixity of one end fixed, other end supported.

All screws with curves which pass through or above and to the right of the plotted point are suitable for the example. The acceptable velocities shown by this graph apply to the screw shaft selected and are not indicative of the velocities attainable of all of the associated ball nut assemblies. Consult Thomson engineering for high speed applications.

†80% of critical speed

Engineering Guidelines for Inch Series Ball Screws

Life Expectancy for Precision Ball Screw Assemblies



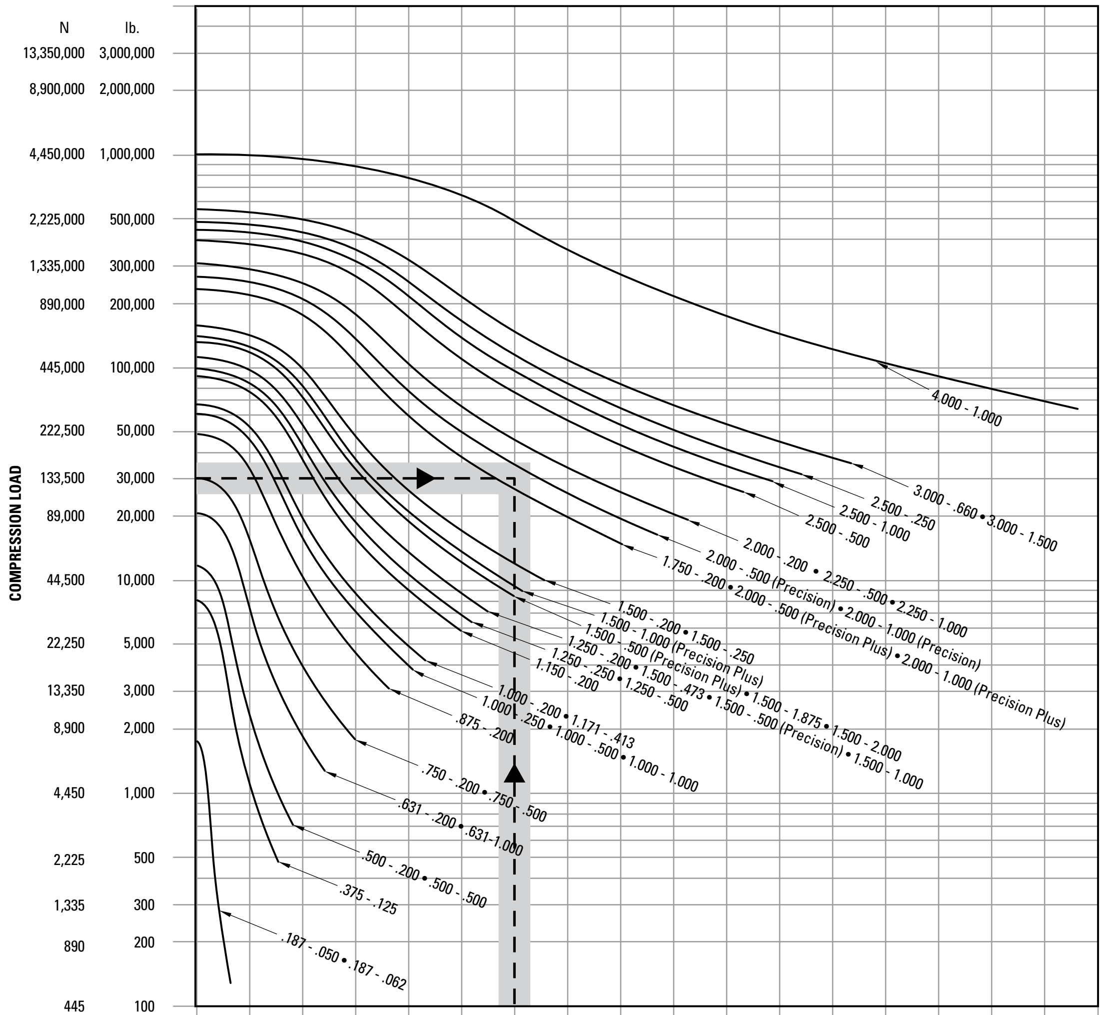
C1 = Single Circuit   C2 = Double Circuit   SC = Standard Capacity   HC = High Capacity

Example: Application life expectancy (total travel) desired is 2 million in. (50.8 million mm).
Normal operating load is 10,000 lb. (44,500 N).

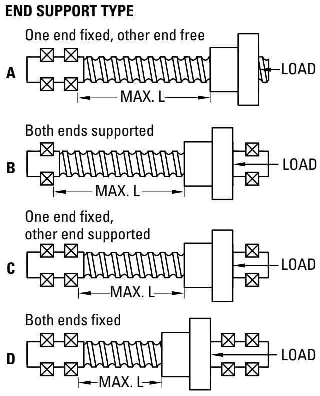
All screws with curves which pass through or are above and to the right of the plotted point are suitable for the example. The suitable dynamic life expectancies shown in this graph are not to exceed the maximum static load capacity as given in the rating table for the individual ball nut assembly.

Engineering Guidelines for Inch Series Ball Screws

Compression Load vs. Length for Designated Ball Screws



END SUPPORT TYPE



A	Inches	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
	mm	127	254	381	508	635	762	889	1016	1143	1270	1397	1524	1651	1778	1905	2032	2159
B	Inches	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	mm	254	508	762	1016	1270	1524	1778	2032	2286	2540	2794	3048	3302	3556	3810	4064	4318
C	Inches	14	28	42	57	71	85	99	113	127	141	156	170	184	198	212	226	240
	mm	356	711	1067	1448	1803	2159	2515	2870	3226	3581	3962	4318	4674	5029	5385	5740	6096
D	Inches	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340
	mm	508	1016	1524	2032	2540	3048	3556	4064	4572	5080	5588	6096	6604	7112	7620	8128	8636

Example: Maximum system load is 30,000 lb. (133,500 N).
Length of 85 in. (2159mm).
End fixity of one end fixed, other end supported.

All screws with curves which pass through or above and to the right of the plotted point are suitable for the example.

The suitable compression loads shown in this graph are not to exceed the maximum static load capacity as given in the rating table for the individual ball nut assembly.

Engineering Guidelines for Metric Series Ball Screws

Selecting a Ball Screw Assembly for Your Application — Metric Series

Below is a list of the most common (but not complete) design considerations used to select a ball screw assembly.

- Compression and/or Tension Load
- Linear Velocity
- Positional Accuracy and Repeatability
- Required Life Expectancy
- Mounting Configuration
- Dimensional Constraints
- Input Power Requirements
- Environmental Condition

At a minimum, the design load, maximum linear velocity, and positional accuracy deired should be the known inputs and are used to calculate the minimum diameter, lead, and needed load capacity of the ball screw assembly. Individual ball screw components are then selected based on life, dimensional constraints, mounting configuration, and environmental conditions.

The following procedure will take you through the most common application-based selection of a ball screw assembly. As no two applications are the same, so the determination process is never the same.

1. Determine the required positional accuracy and repeatability that your application requires (page 154). Backlash is the linear independent motion between the ball screw and the ball nut and can be controlled by preloading the ball nut (page 159). The manufacturing process, rolled screws versus ground screws, dictates the accuracy (page 155).
2. Determine how you plan to mount the ball screw assembly into your machine (see page 156). The configuration of the end supports and the travel distance (Max L) will dictate the load and speed limitations of the ball screw.
3. A ball nut in tension can handle loads up to the rated capacity of the nut. For a ball nut in compression, calculate the Permissible Compression Loading (page 153) or use the Compression Loading Chart (page158) to select a ball screw diameter that meets or exceeds your design load.
4. Calculate the lead of the ball screw that will produce the speed requirement (page 151).
5. The ball nut life can then be calculated using the Dynamic Load Rating (C_{am}) provided in the catalog detail pages. Since multiple ball nuts may be available for a given diameter and lead, use the catalog pages for specified diameter and lead to select available styles.
6. Every ball screw has a rotation speed limit, which is the point of excessive vibration/harmonics in the screw. The critical speed is dependent on the end support configuration. Calculate the Critical Screw Speed of the chosen ball screw (page 153) or use the Acceptable Speed Chart (page 157) to determine the critical speed.
7. If the load, life and speed calculations confirm that the selected ball screw assembly meets or exceeds the design requirements, then proceed to the next step. If not… Larger diameter screws will increase the load capacity and increase the speed rating. Smaller lead screws will decrease the linear speed (assuming constant input motor speed), increase the motor speed (assuming constant linear speed), and decrease the input torque required. Higher lead screws will increase the linear speed (assuming constant input motor speed), decrease the input motor speed (assuming constant linear speed), and increase the input torque required. Repeat steps 3 thru 5 until the correct solution is obtained.
8. Determine how the ball nut will interface into your application. A ball nut flange is the typical method of attaching the ball nut to the load. Threaded ball nuts and cylindrical ball nuts are alternative ways to provide the interface.
9. Additional design considerations and features are also available. Preloaded ball nuts are available to reduce system backlash and increase positional accuracy. Wiper kits to protect the assembly from contaminants and to contain lubrication are standard on some units and optional on most others. Bearing supports and end machining are also available as options for all ball screws.
10. The final considerations are system mounting and lubrication. The ball nut should be loaded axially only as any radial loading significantly reduces the performance of the assembly (page 156). The assembly should also be properly aligned with the drive system, bearing supports, and load to achieve optimal performance (page 156). The ball screw assembly should never be run without proper lubrication. Many lubricants are available depending on the application and environment (page 156).

Note: Application and customer service support is available to assist in the selection of your ball screw assembly. Please contact your local Thomson representative or the customer support center (1-540-633-3549 — TCS) for any additional assistance.

Engineering Guidelines for Metric Series Ball Screws

Ball Screw Assembly Selection Example:
Inputs:

Load: 133,440 N Compression Maximum
44,480 N dynamic
Linear Speed: 5.08 meter/min.
Input Speed: 400 rpm
Travel: 2159 mm
Life: 2.5 x 10^4 meters

1. **Accuracy (pages 154 and 155)**
No Preload and Standard Rolled (±50 µm per 300mm)

2. **End Supports (page 153)**
Fixed/Supported

3. **Determine Screw Diameter**
From Chart (page 158): Ø50mm

From Equation (page 157): $133{,}440 / .8 = \dfrac{1.47 \times 9.687 \times 10^4 \times d_r^4}{(2159)^2}$

therefore, d_r = 44.8mm

4. **Determine Lead**

$\text{Lead} = \dfrac{5.08 \text{ meter/min.}}{400 \text{ rpm}}$ therefore, Lead = 12.7mm, Use 10mm

5. **Determine Life**
From Catalog (page 102): Dynamic Load = 66,400 N

$\text{Life (revolutions)} = \left[\dfrac{66{,}400}{44{,}480}\right]^3 \times 10^6$

therefore, Life = 3.3 x 10^6 revs (3.3 x 10^4 meters)

6. **Determine Critical Speed**
From Catalog (page 102): Screw Root Diameter is 43.0mm

From Equation (page 153): $.8 \times 1.47 \times 1.2 \times 10^6 \times \dfrac{d_r}{l^2}$

therefore, Speed = 1,301.8 rpm

Verified via Chart (page 157)

7. **Design Verification**
OK per load, speed and life.

8. **Load Interface**
Flanged connection preferred.

9. **Additional Requirements**
   - Wipers required
   - Bearing Supports required
   - End Machining needed
   - Right Hand Thread
   - Carbon Steel

10. **Mounting and Lubrication**
System will require motor interface and linear rails for alignment.
TriGel 450R

Product Selection:

Ball Nut: P/N KGF-D-5010-RH-KK

Engineering Guidelines for Metric Series Ball Screws

Design Formulas

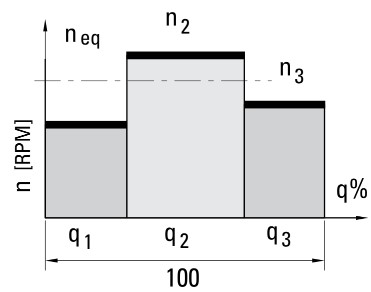
These formulas allow you to calculate a number of important factors which govern the application of Thomson ball screws.

1. Ball Screw Life (L)

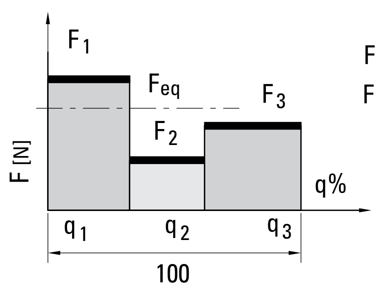
The ball screw assembly's useful life will vary according to load and speed. Life is typically rated at 90% confidence, L10 (which represents time at which 90% of assemblies still perform).

Functional life should be determined by approximating equivalent rotational speed and loading force over typical performance cycles.

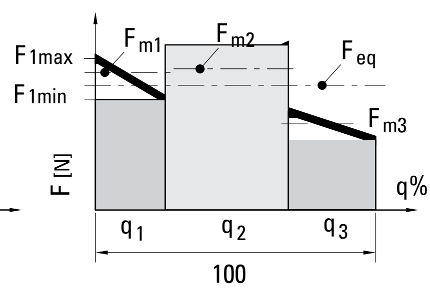
Simple rotational speed profile



Simple loading profile (1)



Simple loading profile (2)



$$n_{eq}\left[\min^{-1}\right] = \sum_{i=1}^{n} n_i \times \frac{q_i}{100}$$

$$F_{eq}\left[N\right] = \left(\sum_{i=1}^{n} F_i^{3} \times \frac{n_i}{n_{eq}} \times \frac{q_i}{100}\right)^{1/3}$$

$$F_{eq}\left[N\right] = \left(\sum_{i=1}^{n} F_{mi}^{3} \times \frac{n_i}{n_{eq}} \times \frac{q_i}{100}\right)^{1/3}$$

Modified Life

$$L_{10}\left[\text{revolutions}\right] = \left[\frac{C_{am}}{F_{eq}}\right]^{3} \times 10^{6}$$

$$L_{h10}\left[\text{hours}\right] = \frac{L_{10}}{n_{eq} \times 60}$$

Parameters:

n_{eq} = equivalent operating rotational speed [rpm]

F_{eq} = equivalent operating load [N]

C_{am} = dynamic load rating [N] (see specification tables) (Based on 1.0 million revolutions)

2. Rotational Speed Required for a Specific Linear Velocity

$$n = \frac{\text{Travel Rate (mm x min.}^{-1}\text{)}}{\text{Lead (mm)}}$$

n = rpm

3. Machine Service Life

After ball screw life (L) is calculated, apply it to the following formula to determine machine service life.

$$\text{Machine Service Life (in years)} = \frac{L_{h10}\,\text{[hours]}}{\text{(machine operating hours)} \bullet \text{(days/year)} \bullet \left(\dfrac{\text{ball screw operating hours}}{\text{machine operating hours}}\right)}$$

Engineering Guidelines for Metric Series Ball Screws

4. Torque

a. Driving torque: T_d (N•m) = $\dfrac{F_{eq} \times P}{2\pi e} = 1.77 \times 10^{-4} \times F_{eq} \times P$

b. Backdrive torque: T_b (N•m) = $\dfrac{F_{eq} \times P \times e}{2\pi} = 1.43 \times 10^{-4} \times F_{eq} \times P$

(conversion of linear to rotational motion)

F_{eq} = Equivalent Operating Load (N)
P = Lead (mm)
e = Efficiency = 0.90
T_d = Driving Torque (N•m)
T_b = Backdrive Torque (N•m)
1 lb-in. = 0.113 N•m

5. Power

$$P_d \text{ (W)} = \frac{F_{eq} \times P}{(2\pi)\, e} \times \frac{n}{9.546 \times 10^3} = \frac{F_{eq} \times P \times n}{5.398 \times 10^4}$$

P_d = Power (W)
n = rpm
1 hp = 746 W

6. Permissible Rotational Speed

The permissible rotational speed depends on two factors: critical screw speed and critical nut speed.

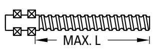
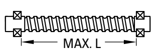
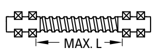
6a. Critical Screw Speed

The critical screw speed is related to the natural frequency of the screw shaft. Exceeding this value may result in excessive vibration. The critical screw speed may be found using the following equations or the chart on page 157.

$$n_c = C_s \times 1.2 \times 10^8 \times \frac{d_r}{l^2}$$

$$n_s = n_c \times S$$

n_c = Critical Speed (rpm)
n_s = Safe Drive Speed
d_r = Root Diameter (mm)
l = Length between Bearing Supports (mm)
S = Safety Factor (0.8 maximum)
C_s = End Fixity Factor

End Fixity Factor - Critical Screw Speed			
End Supports			C_s
A		One end fixed, one end free	0.36
B		Both ends supported	1.00
C		One end fixed, one end supported	1.47
D		Both ends fixed	2.23

6b. Critical Nut Speed

The critical nut speed is related to the velocity of the ball bearings rotating around the screw shaft. Exceeding this value may result in permanent damage to the ball recirculation components. Thomson recommends a maximum DN value of 140,000 for standard internal transfer designs, which encompass the majority of the Metric products. Higher values may be accommodated by special design (consult with applications engineering).

$DN = d_0 n$

where
d_0 = nominal shaft diameter (mm)
n = rotational speed of shaft (rpm)

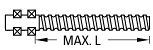
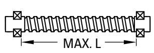
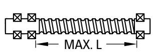
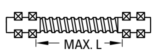
7. Permissible Compression Loading

Exceeding the recommended maximum compression force may result in buckling of the screw shaft.

$$F_c = \frac{C_s \times 9.687 \times 10^4 \times d_r^4}{l^2}$$

$$F_s = F_c \times S$$

F_c = Critical Buckling Force (N)
F_s = Safe Compression Force (N)
d_r = Root Diameter (mm)
l = Max Unsupported Length (mm)
S = Safety Factor (0.8 maximum)
C_s = End Fixity Factor

End Fixity Factor - Permissible Compression Loading			
End Supports			C_s
A		One end fixed, one end free	0.25
B		Both ends supported	1.00
C		One end fixed, one end supported	2.00
D		Both ends fixed	4.00

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Engineering Guidelines for Metric Series Ball Screws

Accuracy Classes

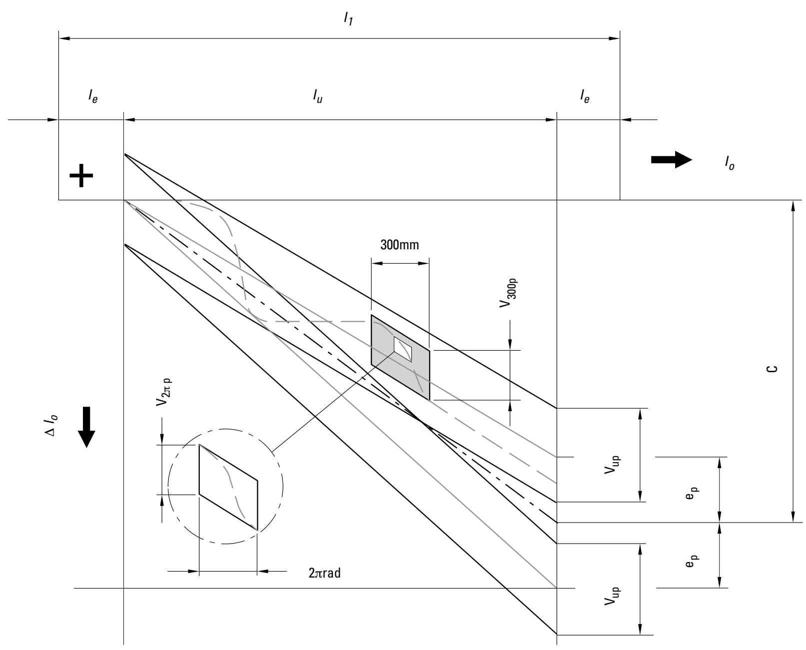
Accuracy is a measure of how closely a motion system will approach a command position. Perfect accuracy, for example, means that advancing a ball nut a precise amount from a given point on the screw always requires exactly the theoretically predicted number of revolutions.

Metric ball screws are produced in two main tolerance classes: T (transport) and P (positioning). Transport grade ball screws are used in applications requiring only coarse movement or those utilizing linear feedback for position location. As such, most transport grade screws are provided with nuts having backlash (T7 grade screws cannot be supplied with preloaded nuts). Precision grade ball screws are used where repeatable positioning within microns is critical, without the use of a linear feedback device.

Differences between P & T grades are highlighted in the graph. T grade transport screws allow greater cumulative variation over the useful length of the screw. P grade positioning screws contain accumulation of lead error to provide precise positioning over the screw's entire useful length.

P — Positioning Class Ball Screws

Maximum error over useful length = $e_p + 1/2V_{up} + C$



l_o = nominal travel

l_1 = thread length

l_o = travel deviation

l_u = useful travel

l_e = excess travel

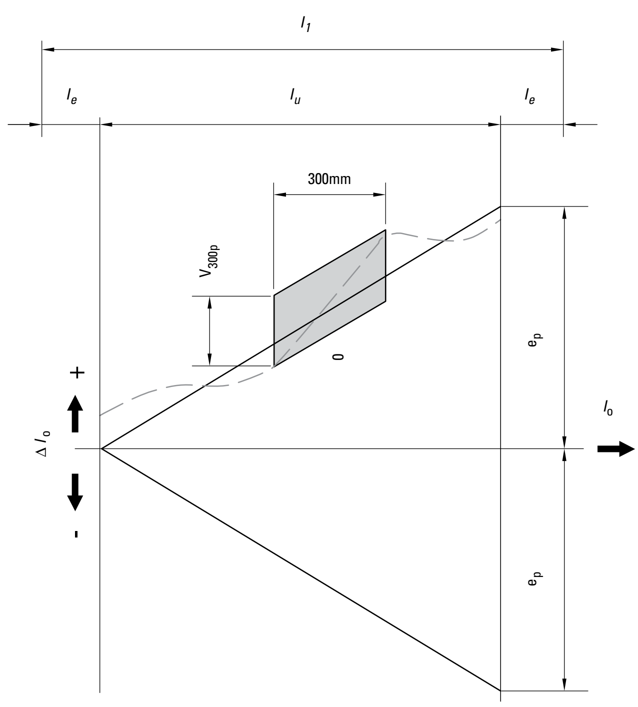
C = travel compensation for useful travel (std. = 0)

e_p = tolerance for actual mean travel deviation (the difference between the maximum and minimum values of the permissible actual mean travel)

V_{up} = permissible travel variation within useful travel, l_u

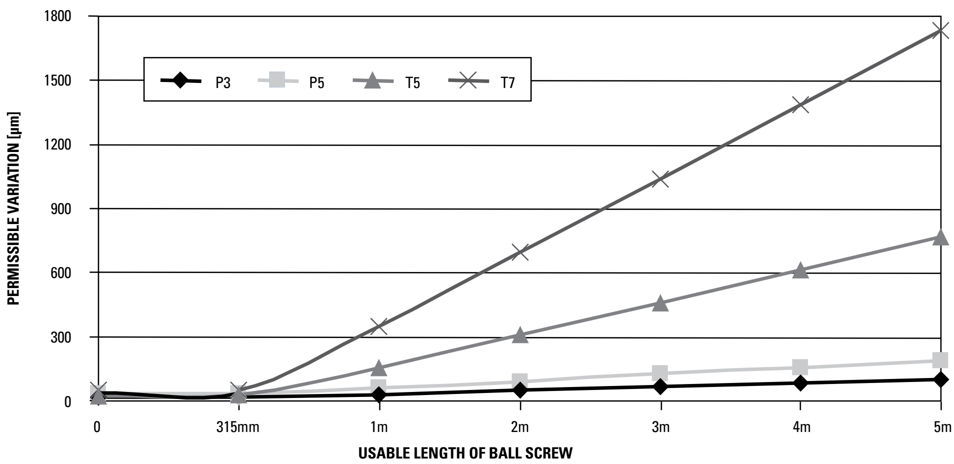
V_{300p} = permissible travel deviation within 300mm travel

$V_{2\pi p}$ = permissible travel deviation within 1 revolution



Engineering Guidelines for Metric Series Ball Screws

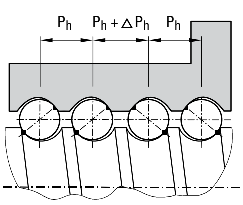
Permissible Travel Variation Over Usable Length



Tolerance Class	Lead Accuracy V_{300p}	Permissible Travel Deviation V_{up} (μm) Over Screw Length l_u (mm)														
		l_u >		315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
		(mm) ?	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300
P3	±12 μm/300mm	e_p (μm)	12	13	15	16	18	21	24	29	35	41	50	62	76	—
		V_{up} (μm)	12	12	13	14	16	17	19	22	25	29	34	41	49	—
P5	±23 μm/300mm	e_p (μm)	23	25	27	30	35	40	46	54	65	77	93	115	140	170
		V_{up} (μm)	23	25	26	29	31	35	39	44	51	59	69	82	99	119
T5	±23 μm/300mm	e_p (μm)	23	$=2 \times l_u/300 \times V_{300p}$												
T7	±52 μm/300mm	e_p (μm)	52	$=2 \times l_u/300 \times V_{300p}$												

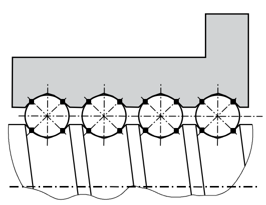
Preload Types

Precise Preload (Type Z0)
(Available with FL nut only)



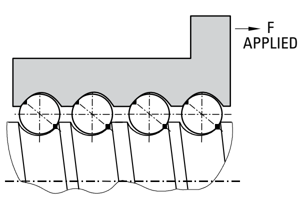
- The lead is offset within the ball nut to provide a precise preload.
- The preload is approximately 10% of dynamic load capacity, but can range from 2% to 13% as specified by customers.
- Typically used where both repeatability and high stiffness are required.

Preload (Type Z1)



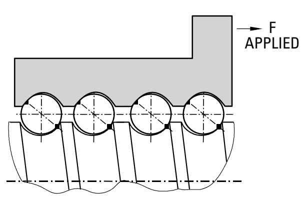
- Oversized balls slightly larger than the ball groove space are used to provide zero backlash between the screw and nut.
- The preload is approximately 1% to 2% of dynamic load capacity.
- Typically used for positioning applications where higher-level repeatability is desired.

No Preload (Type Z2)
(Standard lash)



- Axial play is present between screw and nut.
- Typically used for transport or vertical applications.

No Preload (Type Z3)
(Minimum lash)



- Axial play is present between screw and nut (held to .05mm maximum).
- Typically used for transport or vertical applications.

Engineering Guidelines for Metric Series Ball Screws

Lubrication Guidelines

Ball screws must be lubricated to operate properly and achieve the rated life. We recommend using TriGEL-450R or TriGEL-1800RC for lubricating ball screws. Other oils and greases may be applicable but have not been evaluated.

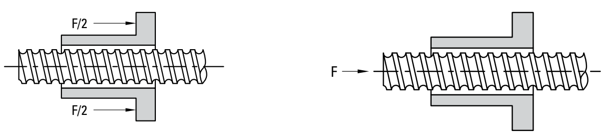
The TriGEL grease can be applied directly to the screw threads near the root of the ball track. Some ball nut sizes are available with threaded lube holes for mounting lubrication fittings. For these ball nuts, the TriGEL grease can be pumped directly into the nut. Please refer to the catalog detail views to verify which ball nuts have the threaded lube holes. It is recommended to use these nuts in conjunction with a wiper kit to contain the lubricant in the body of the nut.

Ball screws may require lubrication frequently frequently depending on both environmental and operating conditions. If the lubricant appears to be dispersed before this point or has become dry or crusted, the maintenance interval should be reduced. Before adding additional grease, wipe the screw clean, removing the old grease and any particulate contamination seen on the screw. If oil is being used, the best results may be obtained by utilizing a continuous-drip type applicator.

Nut Loading

Axial loading (on nut or screw) is optimal for performance and life. For applications requiring radial loads, please contact us.

Axial Loading: optimal

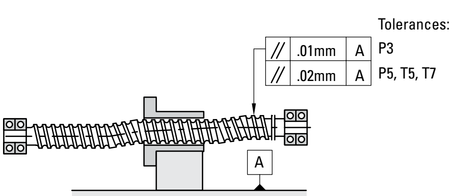


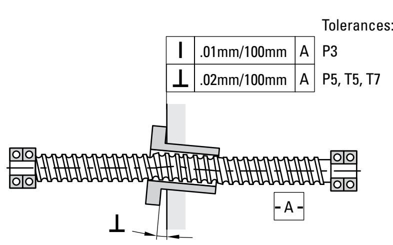
Radial Loading: detrimental*

* Minimize radial loading to less than 5% of the axial load.

Nut Mounting

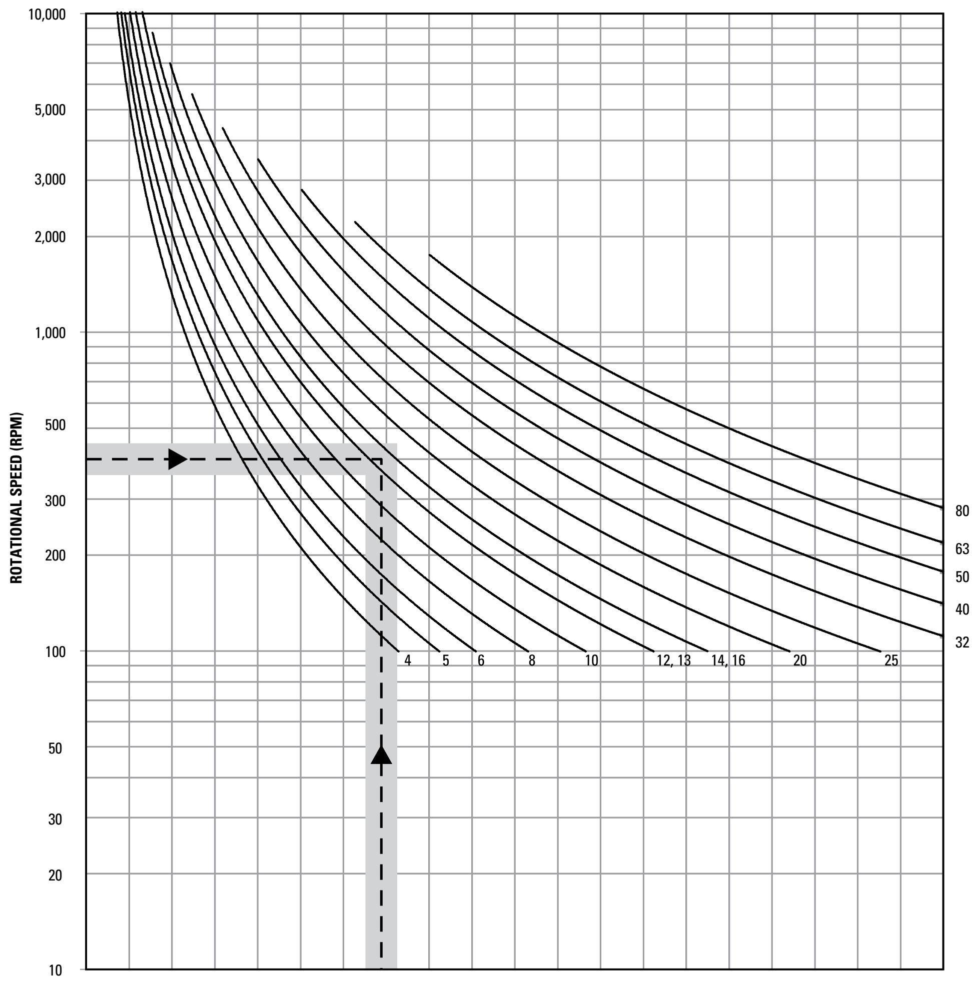
Use the following guidelines to achieve optimal performance. (All units are mm)



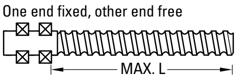
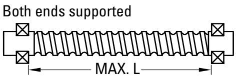
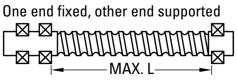
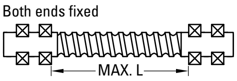


Engineering Guidelines for Metric Series Ball Screws

Acceptable Speed† vs. Length for Screws



END SUPPORT TYPE

A	One end fixed, other end free 	Inches	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
		mm	152	304	457	609	762	914	1056	1219	1371	1524	1676	1828	1981	2133	2286	2438	2590	2743	2895	3048
B	Both ends supported 	Inches	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
		mm	254	508	762	1016	1270	1524	1778	2032	2286	2540	2794	3048	3302	3556	3810	4064	4318	4572	4826	5080
C	One end fixed, other end supported 	Inches	12	24	36	48	61	73	85	97	109	121	133	145	158	170	182	194	206	218	230	242
		mm	304	609	914	1219	1549	1854	2159	2463	2768	3073	3378	3683	4013	4318	4622	4927	5232	5537	5842	6146
D	Both ends fixed 	Inches	15	30	45	60	75	90	105	119	134	149	164	179	194	209	224	239	254	269	284	298
		mm	381	762	1143	1524	1905	2286	2667	3022	3403	3784	4165	4546	4927	5308	5689	6070	6451	6832	7213	7569

Unsupported length of 85 in. (2159mm).

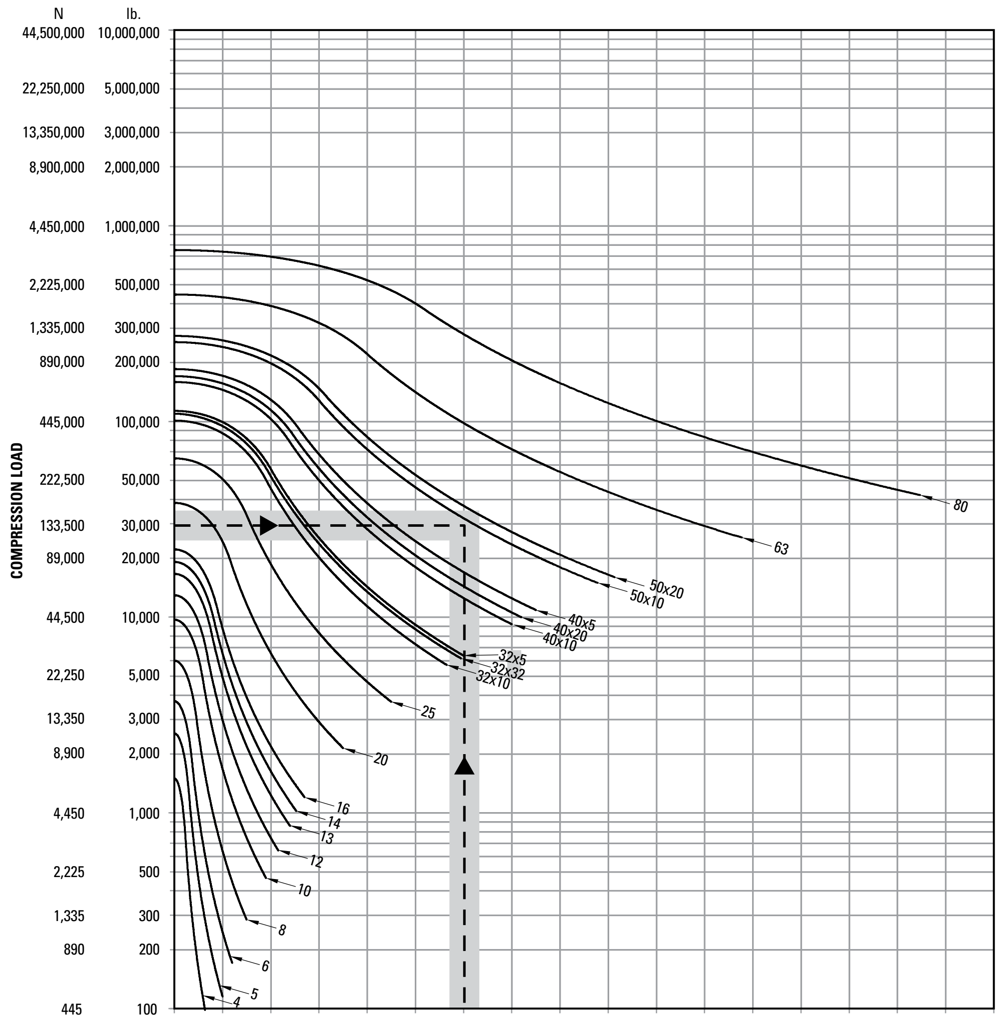
End fixity of one end fixed, other end supported.

All screws with curves which pass through or above and to the right of the plotted point are suitable for the example. The acceptable velocities shown by this graph apply to the screw shaft selected and are not indicative of the velocities attainable of all of the associated ball nut assemblies. Consult Thomson engineering for high speed applications.

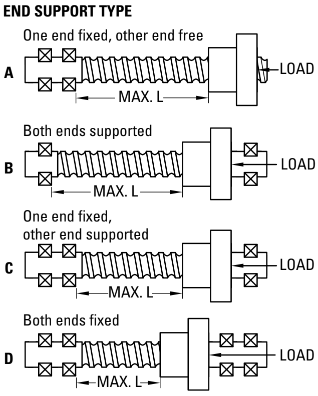
†80% of critical speed

Engineering Guidelines for Metric Series Ball Screws

Compression Load vs. Length for Designated Ball Screws



END SUPPORT TYPE



A	Inches	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
	mm	127	254	381	508	635	762	889	1016	1143	1270	1397	1524	1651	1778	1905	2032	2159
B	Inches	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	mm	254	508	762	1016	1270	1524	1778	2032	2286	2540	2794	3048	3302	3556	3810	4064	4318
C	Inches	14	28	42	57	71	85	99	113	127	141	156	170	184	198	212	226	240
	mm	356	711	1067	1448	1803	2159	2515	2870	3226	3581	3962	4318	4674	5029	5385	5740	6096
D	Inches	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340
	mm	508	1016	1524	2032	2540	3048	3556	4064	4572	5080	5588	6096	6604	7112	7620	8128	8636

Example: Maximum system load is 30,000 lb. (133,500 N).
Length of 85 in. (2159mm).
End fixity of one end fixed, other end supported.

All screws with curves which pass through or above and to the right of the plotted point are suitable for the example.

The suitable compression loads shown in this graph are not to exceed the maximum static load capacity as given in the rating table for the individual ball nut assembly.

Engineering Guidelines for Ball Splines

Selection Procedures

Applications Analysis — Follow this step-by-step procedure to determine the ball spline best suited for your application. It is suggested you analyze the requirements of your application using a work pad for easy reference.

Maximum Static Load — Determine the maximum static torque loads encountered in the application. This must include shock loads. Using the table on page 116, note the ball spline sizes and race combinations which have capacities in excess of the application requirements.

Rated Load — In many ball spline applications, freedom of axial movement is essential while actual travel is negligible. For example, a spline used on a jet engine accessory gear box drive moves less than 1/10 inch. This axial freedom is essential to eliminate damaging stress forces to the engine and gear box housings, but total daily travel may be less than 2 inches. Select the size and race combination with a rated load that will meet your application requirement from the table.

Life Expectancy — On occasion, it is important to plan for a specific life expectancy. These applications usually are designed to use the smallest practical ball spline at the maximum possible torque or where considerable translation occurs. For these applications, use the Life Expectancy chart on page 165. Contact Thomson if light weight and small size are considerations.

Determine the following:

- life expectancy — total inches of travel desired during the life of the application
- application load — the normal operating load for the application in inch-pounds (Newton-millimeters) of torque

Speed vs. Length — Determine the following:

- Speed — determine the maximum revolutions per minute (rpm) required
- Maximum length — determine the maximum unsupported length
- End fixity — determine the type of configuration (refer to the Bearing Support reference drawings on page 146). Quick Mount bearing support blocks can be used on diameters 5/8 inch through 2-1/2 inch. Using the example at the bottom of the Speed vs. Length chart on page 161, plot the point for your specific application.

Design Formulas

Life Ratings

$$L_{10}\,[\text{in.}] = \left[\frac{C_{am}}{T}\right]^3 \times 10^6$$

Parameters:

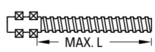
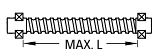
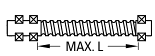
T = dynamic equivalent torque (A constant torque under the influence of which a ball spline assembly would have the same life as it will attain under the actual applied torque condition.)

C_{am} = dynamic load rating [lbs.] (based on 1.0 million inches)

$$n_c = C_s \times 4.76 \times 10^6 \times \frac{d_r}{l^2}$$

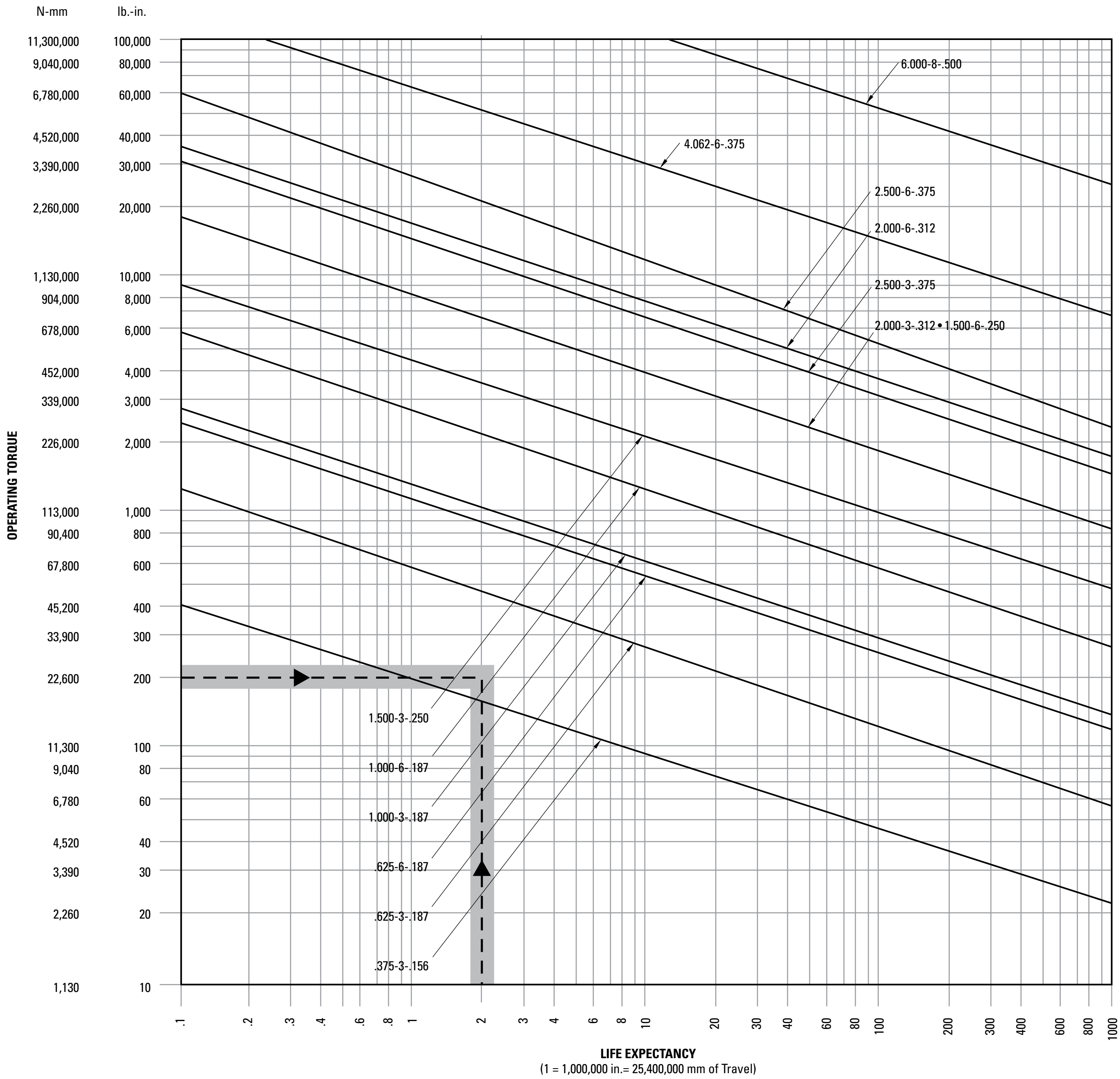
$$n_s = n_c \times S$$

n_c = Critical Speed (rpm)
n_s = Safe Drive Speed
d_r = Root Diameter (in.)
l = Length between Bearing Supports (in.)
S = Safety Factor (0.8 maximum)
C_s = End Fixity Factor

End Fixity Factor			
End Supports			C_S
A		One end fixed, one end free	0.36
B		Both ends supported	1.00
C		One end fixed, one end supported	1.47
D		Both ends fixed	2.23

Engineering Guidelines for Ball Splines

Life Expectancy for Precision Ball Splines

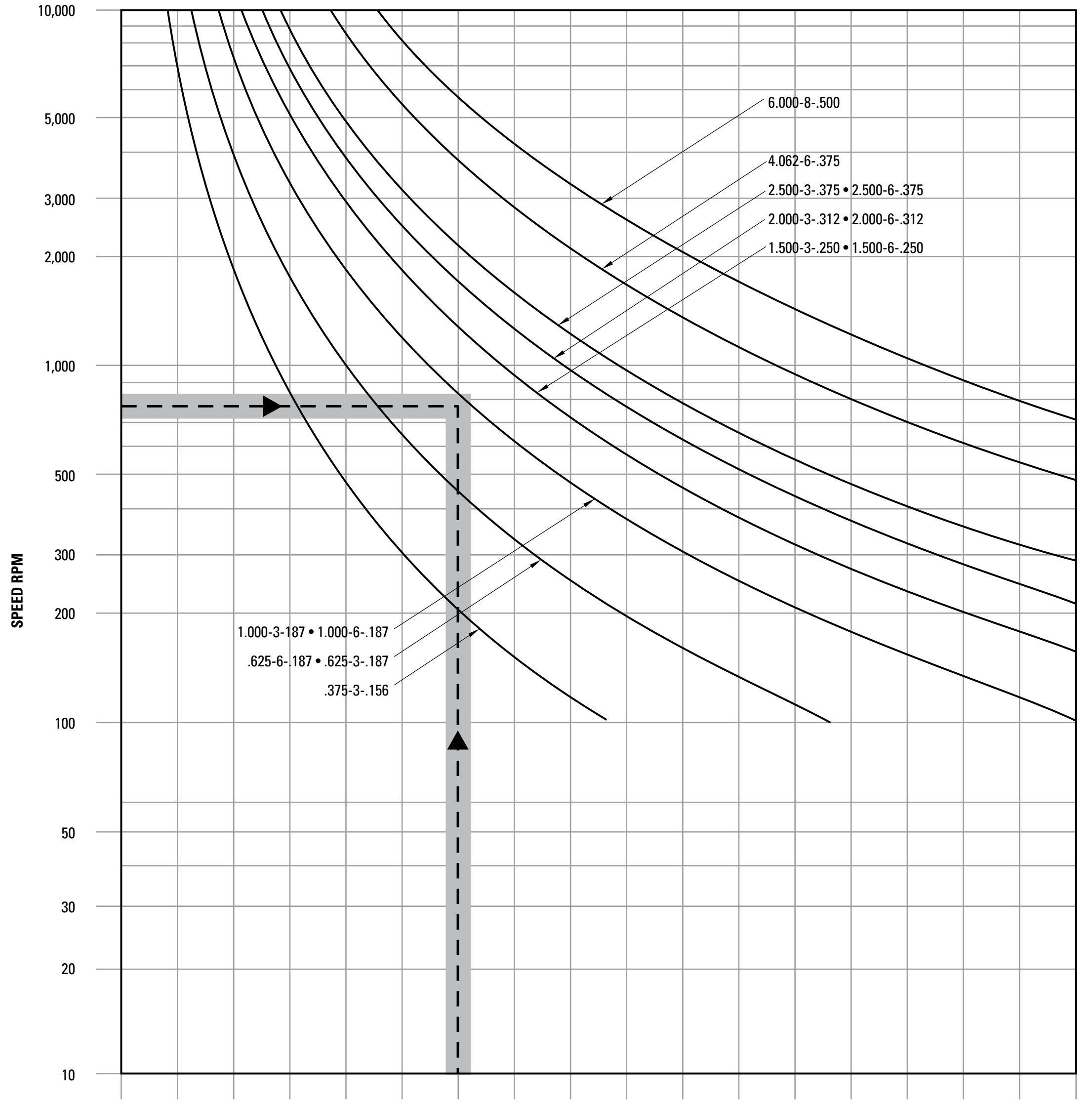


Example: Desired life of 2 million in.
(50.8 million mm).
Operating torque is 200 lb-in.
(22.6 N · mm)

All splines with curves which pass through or are above and to the right of the plotted point are suitable for the example.

Engineering Guidelines for Ball Splines

Speed vs. Length for Precision Ball Splines



END SUPPORT TYPE

End support type	Unit																	
A — One end fixed, other end free (MAX. L)	Inches	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102
	mm	152	304	457	609	762	914	1056	1219	1371	1524	1676	1828	1981	2133	2286	2438	2590
B — Both ends supported (MAX. L)	Inches	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	mm	254	508	762	1016	1270	1524	1778	2032	2286	2743	2794	3048	3302	3556	3810	4064	4318
C — One end fixed, other end supported (MAX. L)	Inches	12	24	36	48	61	73	85	97	109	121	133	145	158	170	182	194	206
	mm	304	609	914	1219	1549	1854	2159	2463	2768	3073	3378	3683	4013	4318	4622	4927	5232
D — Both ends fixed (MAX. L)	Inches	15	30	45	60	75	90	105	119	134	149	164	179	194	209	224	239	254
	mm	381	762	1143	1524	1905	2286	2667	3022	3403	3784	4165	4546	4927	5308	5689	6070	6451

Example: Maximum shaft speed is 800 rpm.
Unsupported length is 60 in. (1524mm).
End fixity is both ends supported.

All splines with curves which pass through or are above and to the right of the plotted point are suitable for the example.

Installation

This section is organized so that the installer can follow step by step instructions to prepare and install a new ball screw assembly. Ball screw assemblies are offered in several variations, so all of the installation steps may not be followed for a specific type. The Glossary of Terms will define any terms with which the user may not be familiar. All product specifications and dimensions are found in this catalog.

Installation Can Be Completed in Six Easy Steps

STEP ONE:	Mounting the Flange to the Ball Nut
STEP TWO:	Mount Front End of Wiper to the Screw (brush type wipers only)
STEP THREE:	Install Ball Nut onto the Ball Screw
STEP FOUR:	Complete Installation of the Wiper Kit
STEP FIVE:	Lubricate the Ball Nut and Screw
STEP SIX:	Install Ball Screw Assembly into Your Machine

Ball screws are delivered to the user in one of four ways:

1. Finished ends with assembled ball nut, ready to mount in a machine. No further preparation is required.
2. Screw ends machined and ball nut supplied on an arbor ready for transfer.
3. Screw cut and annealed ready for machining and ball nut supplied on an arbor ready for transfer.
4. Hardened screw in bulk length with ball nut supplied on an arbor ready for transfer.

Ball nuts are delivered without flanges attached and without lubrication. **Ball screw assemblies must not be run without proper lubrication.**

STEP ONE: Mounting the Flange to the Ball Nut

If flange is not used, proceed to STEP TWO.

Preparation of Ball Nut

A ball nut flange is the recommended means of attaching a ball nut to a load. A flange should be tightened firmly against the ball nut on its threads and secured by the method described below. Take care not to grasp and damage the return tubes when tightening the flange. Ball circulation will be impaired if the return tubes are damaged.

Flanges are provided loose from the factory unless otherwise specified. The standard method to secure the flange to the ball nut is shown in Method "A" (retain with pins). Smaller ball screw assemblies may be assembled using Method "B" (retain with set screws). Flanges can be pinned at the factory upon request.

Flange Installation Method A

Retain with pins (recommended)

1. Remove the ball nut from the transfer arbor. Catch and save the balls for reassembly.
2. Face shoulder on ball nut with lathe to achieve proper orientation.
3. Thread the flange onto the ball nut until it contacts the ball nut shoulder.
4. Loosen the flange until the required machine bolts can be inserted into the flange mounting holes without interfering with the ball return guides (see Figure 1).
5. Drill two holes approximately 90° apart, as shown in Figure 1. Note: the pin circle diameter is also the V-thread pitch diameter.
6. Press two groove type pins to the bottom of the drilled holes.
7. Stake the pin holes to prevent the pins from disengaging.
8. Remove all chips from the ball nut, and clean it thoroughly to remove potential contaminants.
9. Reassemble the flanged ball nut and components on the transfer arbor or ball screw.

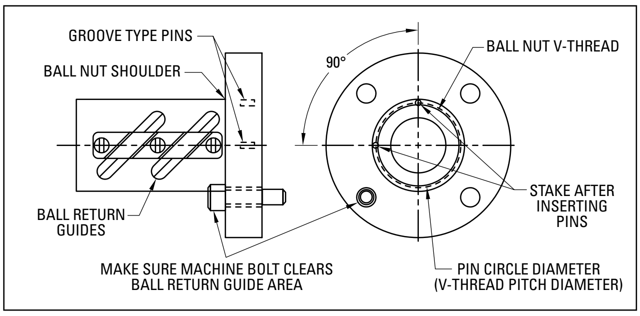


Figure 1

Installation

Flange Installation Method B

Retain with set screws (optional for flanges with set screws)

1. Apply Loctite grade 271 (red in color) to the ball nut V-threads.
2. Thread the flange onto the ball nut until it contacts the ball nut shoulder.
3. Loosen the flange until the required machine bolts can be inserted into the flange mounting holes without interfering with the ball return guides (see Figure 2).
4. Apply Loctite grade 271 (red in color) to the radial threaded hole in the flange.
5. Select a cup point set screw with a length of one half the threaded hole depth. Install two set screws, tightening to the manufacturer's recommended torque (see Figure 2).

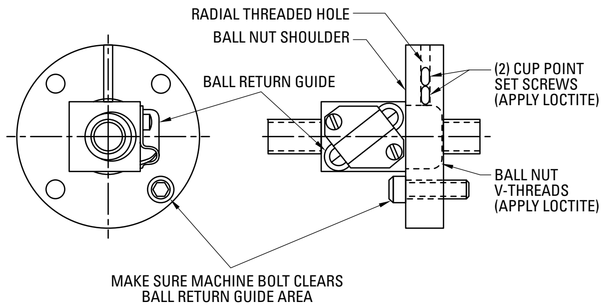


Figure 2

Method B Dimensions

V-Thread	Reference			Pin Circle Diameter	Drill		Pin	
	BCD	Lead	Ball Diameter		Diameter	Depth	Diameter	Length
.664-32 UNS	0.375	0.125	0.063	Use Method A — Retain with set screws				
0.6875-24 UNEF	0.375	0.125	0.063					
0.9375-16 UN	0.500	0.200	0.125					
0.9375-16 UN	0.500	0.500	0.125					
0.9375-16 UN	0.631	0.200	0.125					
0.9375-16 UN	0.631	1.000	0.125					
1.173-18 UNS	0.750	0.200	0.125					
1.125-18 UNEF	0.750	0.200	0.125					
1.250-18 UNEF	0.750	0.200	0.125					
1.173-18 UNS	0.750	0.500	0.156					
1.250-16 UN	0.750	0.500	0.156					
1.375-16 UN	0.875	0.200	0.125	1.332	0.094	0.312	0.094	0.250
1.563-18 UNEF	1.000	0.250	0.156	1.527	0.125	0.438	0.125	0.375
1.563-18 UNEF	1.000	0.500	0.156	1.527	0.125	0.438	0.125	0.375
1.563-18 UNEF	1.000	1.000	0.156	1.527	0.125	0.438	0.125	0.375
1.625-20 UN	1.150	0.200	0.125	1.591	0.094	0.312	0.094	0.250
1.967-18 UNS	1.171	0.413	0.281	1.929	0.188	0.438	0.188	0.375
1.967-18 UNS	1.500	0.250	0.156	1.929	0.125	0.312	0.125	0.250
2.548-18 UNS	1.500	0.473	0.344	2.509	0.250	0.438	0.250	0.375
2.360-18 UNS	1.500	0.500	0.312	2.337	0.250	0.438	0.250	0.375
2.250-20 UN	1.500	1.000	0.344	2.215	0.250	0.562	0.250	0.500
2.250-20 UN	1.500	1.875	0.281	2.215	0.188	0.562	0.188	0.500
2.250-20 UN	1.500	2.000	0.281	2.215	0.188	0.562	0.188	0.500
3.000-12 UN	2.000	0.500	0.375	2.944	0.250	1.000	0.250	0.625
3.000-12 UN	2.000	1.000	0.375	2.944	0.250	1.000	0.250	0.625
3.137-12 UNS	2.250	0.500	0.375	3.080	0.250	1.000	0.250	0.625
3.137-12 UNS	2.250	1.000	0.375	3.080	0.250	1.000	0.250	0.625
3.340-12 UNS	2.500	0.250	0.156	3.283	0.125	0.750	0.125	0.500
3.625-12 UN	2.500	0.500	0.375	3.443	0.250	1.000	0.250	0.625
3.625-12 UN	2.500	1.000	0.375	3.443	0.250	1.000	0.250	0.625
4.325-12 UNS	3.000	0.660	0.500	4.267	0.250	1.188	0.250	0.750
4.325-12 UNS	3.000	1.500	0.500	4.267	0.250	1.188	0.250	0.750
5.497-12 UNS	4.000	1.000	0.625	5.439	0.375	1.250	0.375	0.750

Installation

STEP TWO: Mount Front End of Wiper to the Screw

If wiper is not included or integral to ball nut, then proceed to STEP THREE.

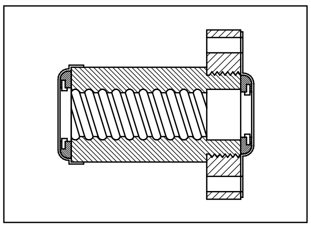
Wipers

Wipers are available for most units as optional items. Precision inch ball nuts typically do not include wipers but they may be added as an option. Precision Plus inch ball nuts and all metric ball nuts include wipers as standard. Wipers generally fall into two categories: one style is internally mounted inside the extreme ends of the ball nut; the other is a wiper and retainer kit combination mounted on the exterior end of the ball nut. In some applications, one or the other may be used or a combination of both. Visual inspection will reveal the style used.

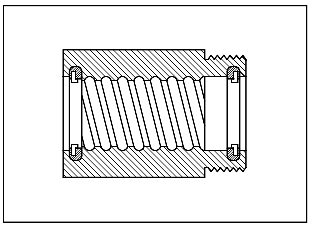
To obtain maximum service from a ball screw assembly, the ball nut should be protected from metal chips and dirt. Foreign material entering the ball nut may be rolled into the ball race, causing high localized loading, abrasion and spalling of the balls, resulting in premature failure. The wiper helps prohibit contaminants from entering the nut as it translates along the screw. These wipers are effective in most industrial applications.

For wipers with flange retainer: 1) Select end of screw to install ball nut (typically end with shortest journal length). 2) Orient ball nut with flange facing desired direction. 3) Install wiper holder and wiper for leading end of ball nut to ball screw. Then follow the ball nut installation procedure, STEP THREE, page 220) Install wiper holder onto trailing end of ball nut once the ball nut is installed on the ball screw.

Brush Wiper

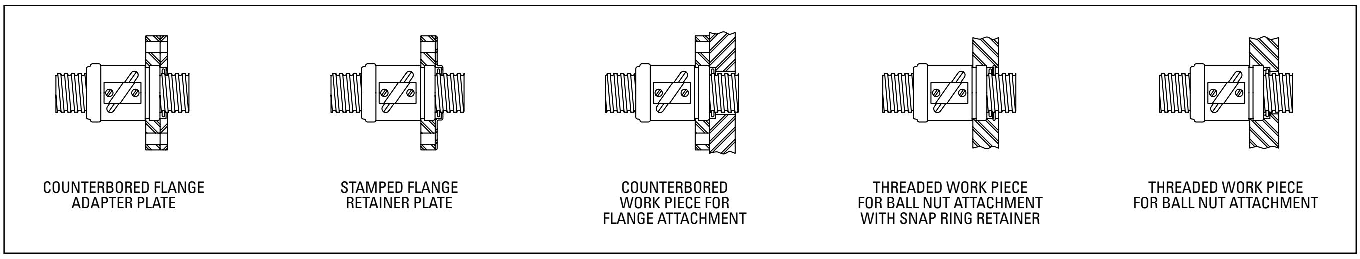


Wiper with Flange Retainer



Internal Snap Ring

Typical Methods of Attaching Wipers to V-Thread End



Wiper without Flange Retainer

Installation

STEP THREE: Install Ball Nut onto the Ball Screw

Installing Ball Nut onto Ball Screw

Each ball nut is completely assembled and loaded with bearing balls before it leaves the factory. The balls are held in place by a shipping arbor/mandrel.

CAUTION: If the arbor is removed without turning the nut onto the screw, the bearing balls will fall out of the nut and will require reloading.

Method A: Install Ball Nut without Preload onto Ball Screw

Method B: Install Ball Nut with Preload onto Ball Screw Using Gap Technique (required on part numbers listed in Table B)

Method C: Install Ball Nut with Preload onto Ball Screw Using Turn Technique (required on part numbers listed in Table C)

Method A: Install Ball Nut without Preload onto Ball Screw

To transfer the ball nut to the screw, proceed as follows:

1. Remove any ball nut retainer from the arbor. Hold the arbor firmly end to end with the screw. Make certain the arbor end is centered on the screw shaft end. (See Figure 3.)

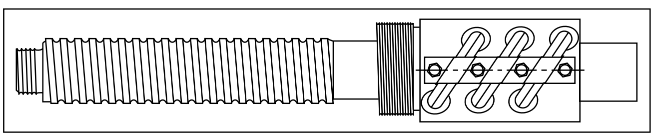


Figure 3

2. Slide the ball nut down to the screw shaft and rotate to the thread until you feel the balls drop into the screw thread. Then rotate with the screw thread until the ball nut completely clears the end of the screw shaft adjacent to the arbor. (See Figure 4.)

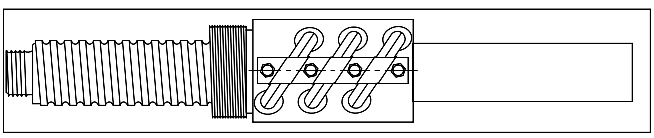


Figure 4

3. Remove the arbor. (See Figure 5.)

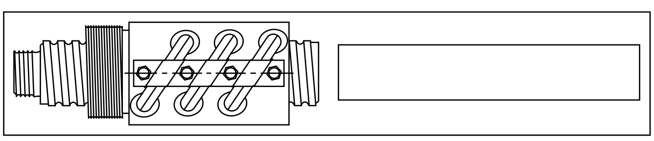


Figure 5

To transfer the ball nut to the arbor, reverse these steps.

CAUTION: When end machining makes it impossible to bring the arbor adjacent to the shaft ball grooves, wrap the machined portion with tape to the nominal O.D. of the arbor. The tape will permit the ball nut to slide over the machined area without the balls dropping into machined irregularities in the shaft.

CAUTION: Extreme care must be taken to prevent the ball nut from sliding off the end of the screw shaft during installation and handling. Temporary stops can be made by wrapping tape around the shaft ball grooves at each end. Be sure to remove the tape and any residual adhesive after the ball screw assembly is properly installed.

Notes regarding installation of Preloaded Ball Nuts (Applicable to Methods B and C):

Installing Preloaded Double Nut
Preloaded Ball Screws (Double Nut Design)

General Description: The two primary reasons for preloading ball screws are to: eliminate backlash and obtain maximum system stiffness.

Preload for units having a compensating spring feature should be established in excess of the normal operating load whenever possible. Further adjustment is not normally required during the life expectancy. Units of this type are used in many specific applications requiring special considerations.

Transferring Ball Nuts from Arbor

Double nut design ball nuts are supplied on arbors. Care must be used not to lose any of the bearing balls, or trap balls between circuits when rotating the ball nut onto the screw.

Method B: Install Ball Nut with Preload onto Ball Screw Using Gap Technique (required on part numbers listed in Table B)

Use this procedure for assemblies having part numbers indicated in Table B.

Preloading Double Nuts Using Gap Technique

Ball nuts are transferred from arbor without a preload. Before preloading these ball nuts, oil the coupling threads, spring washers, ball nut bearing surfaces and the ball grooves of the screw shaft.

Be sure to keep the ball return tubes of the two ball nuts aligned (see Figure 6). Also, make sure the coupling tangs line up with the slots in the ball nut if they have become disengaged.

Position the ball nut midway on the screw shaft. Place retainers on screw to prevent the ball nut from accidentally running off the screw shaft. With the ball return tubes facing upwards, tighten the spanner nut against the spring washer "finger tight", plus 1/4 turn. Rotate the screw shaft through several turns in both directions while holding the ball nut with the ball return tubes on top. Continue to tighten the spanner nut with spanner or channel locks until the .003" (075mm) average gap is obtained resulting in the preload as indicated by the chart. Rotate the screw in both directions several times and check for smoothness. Be sure the spring washer of the coupling is centralized (not protruding in any direction). Use a plastic or brass mallet, if necessary, to help seat the coupling system. Tap lightly. Recheck torque and re-average gap as necessary.

Check the torque by rotating screw shaft with a torque wrench. Secure the spanner nut with the set screw(s) provided.

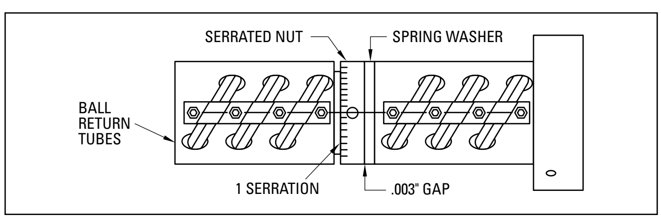


Figure 6

Installation

Table B. Preload Using Gap Technique

Ball Nut Nominal Size & Lead	Ball Nut P/N	Preload Lbs (Newtons) at .003" Gap	Torque In-Lbs (N-mm) at .003" Gap
.500 x .500	7826767	150 (667)	1.0 (113)
.631 x .200	7820955 / 7820956 7823584	150 (667)	1.0 (113)
.631 x 1.000	7827531	50 (222)	50 (222)
.750 x .500	7826991	220 (979)	1.5 (170)
.875 x .200	7823585/7833677	220 (979)	1.5 (170)
1.000 x .250	5704167 / 5704168	330 (1468)	2.0 (226)
1.000 x .250	7820428	330 (1468)	2.0 (226)
1.000 x .250	7820426	330 (1468)	2.0 (226)
1.000 x .250	7823586	330 (1468)	2.0 (226)
1.000 x 1.000	7829720	330 (1468)	2.0 (226)
1.150 x .200	5704270 / 7820206 7823587	240 (1068)	1.5 (170)
1.500 x .250	5704271 / 7823588 7833234 / 5704573	920 (4092)	5.5 (622)
1.500 x 1.000	5700698	1550 (6894)	10.0 (1130)
1.500 x 1.875	5704272	1550 (6894)	10.0 (1130)
2.250 x .500	7823589	5000 (22240)	30.0 (3390)
2.500 x .250	7823590	1300 (5782)	10.0 (1130)
3.000 x .660	5703045	12400 (55155)	75.0 (8475)

Method C: Install Ball Nut with Preload onto Ball Screw Using Turn Technique (required on part numbers listed in Table C)

Use this procedure for assemblies having part numbers indicated in Table C.

Preloading Double Nuts Using Turn Technique

Turn the locknut onto the V-threads of the rear nut until it shoulders against the nut (Figure 7). Do not tighten the set screws yet.

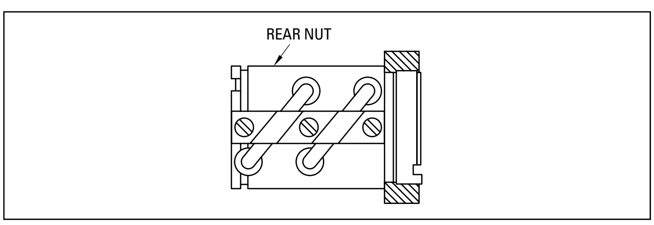


Figure 7. Assembly of locknut to rear nut.

Turn the front nut onto the screw as shown in Figure 10 Insert the tanged sleeve into position against the front nut with preload springs oriented as shown in Figure 8.

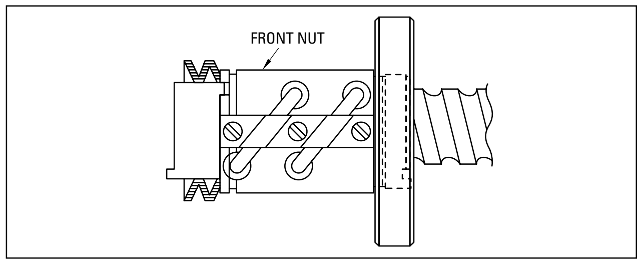


Figure 8. Preload spring orientation.

Insert the slots of the rear nut (lock nut end) into the tangs of the preload sleeve and turn the rear nut onto the screw. Both nuts now turn as an assembly with the tangs in full engagement to prevent the two nuts from rotating separately. The return tubes of the two nuts should be in line with one another. The adjuster nut must be loose at this point, not compressing the belleville springs. (See Figure 9.)

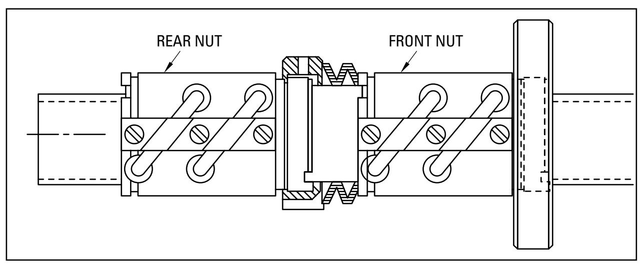


Figure 9. Assembly of rear nut to preload spring.

Hand turn the locknut until all freeplay is just removed. At this point, further turning will begin compressing the preload springs and begin to set the preload force.

Assembly

Transfer the front nut, with flange attached, onto the ball screw as shown in Figure 10. The nut should be turned onto the screw only far enough to avoid loss of bearing balls upon removing the mandrel.

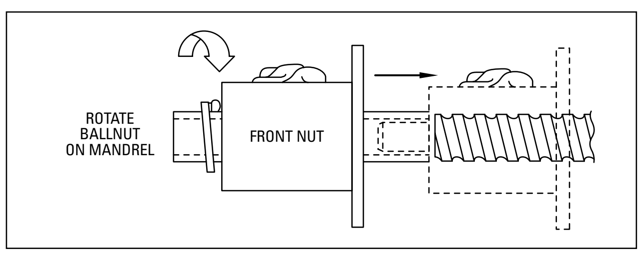


Figure 10. Transfer of front nut to screw.

Installation

Method C (Continued)

Bring the rear nut on its mandrel to position for turning onto the screw. (See Figure 11.)

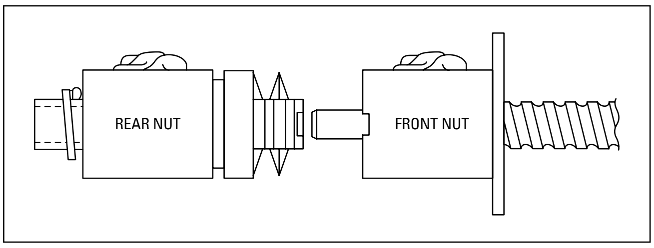


Figure 11. Positioning rear nut for mounting.

NOTE: Normally the rear nut for preloading is shipped fully assembled from the factory. If the spring package is not assembled to the rear nut as shown in Figure 12, review Preload Components Assembly for assembly instructions.

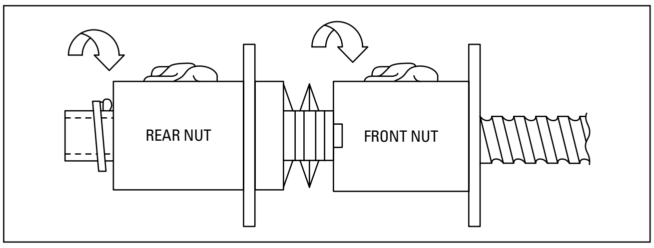


Figure 12. Mounting rear nut.

Insert the tabs of the preload sleeve into the slots of the front nut and then turn the rear nut onto the screw. Both nuts now turn as an assembly with the tangs in full engagement to prevent the two nuts from rotating separately. The return tubes of the two nuts should be in line with one another. The adjuster nut must be loose at this point, not compressing the belleville springs. (See Figure 13.)

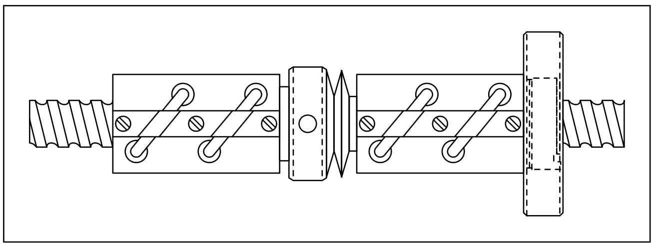


Figure 13. Assembled preload ready for setting.

Turn the locknut until all freeplay is just removed. At this point further turning will begin compressing the preload springs and set the preload force.

Setting the Preload

Amount of Preload

Refer to Table C on page 223 for the Number of Circuits, after freeplay is removed, required for the desired preload. The approximate preload per rotation is also given for preloads between recommended and maximum.

Methods of Setting the Preload

1. Small ball screws with light loads may often be set by hand-turning the adjuster nut to position while preventing rotation of the ball nuts.
2. Ball screws of medium size often require a spanner wrench to turn the adjuster nut to position.
3. Large size units sometimes require a spanner wrench with a pipe extension.

Rotation of the ball nuts during preload setting can be prevented by securing the flange in a fixture or installing the ball screw in its end use application.

CAUTION: Clamping the O.D. of the ball nuts in a vise or similar gripping system to prevent rotation during preload setting is unacceptable due to damage that may be caused to the balls or return tubes of the ball nut.

After setting the preload to the desired preload force, tighten the set screws into the adjuster nut to secure the preload setting.

Preload Components Assembly

Use in conjunction with Assembly instructions on page 221 if assembly of resilient preload components to rear nut is necessary.

Turn the locknut onto the V-threads of the rear nut until the spanner wrench holes line up with the pin holes on the nut. (See Figure 14.)

Do not tighten the set screws at this point.

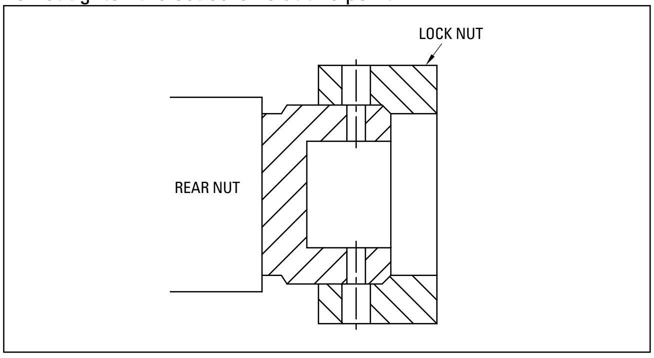


Figure 14. Assembly of locknut to rear nut.

Installation

Method C (Continued)
Insert the sleeve into position with preload springs oriented as shown in Figure 15. Align the sleeve holes for insertion of the spring pins.

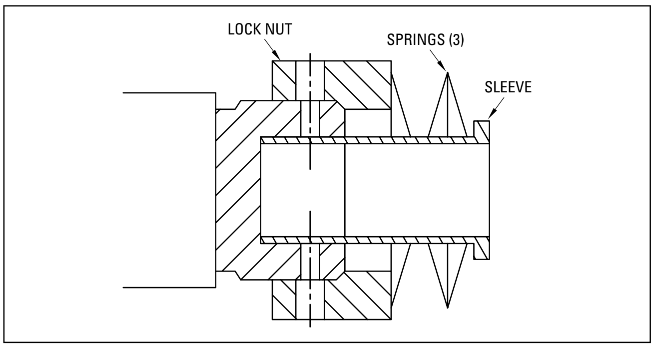


Figure 15. Assembly of sleeve and preload springs.

Press the pins to a depth just below the root of the V-threads in the locknut to allow the locknut to turn freely (see Figure 16). The pins must not be inserted deeper, as they may interfere with the ball screw grooves.

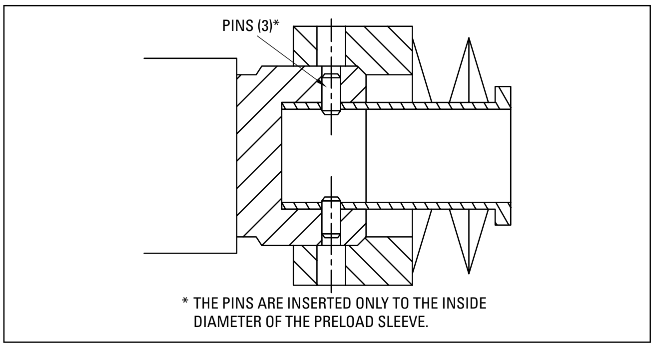


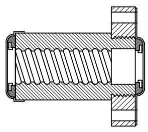
Figure 16. Inserting retainer pin.

Ball Nut Nominal Size & Lead	Ball Nut P/N	Preload Lbs (Newtons)	Turns
.375 x .125	8103-448-004	50	0.29
.375 x .125	8103-448-005	50	0.29
.500 x .200	8105-448-008	120	0.24
.500 x .500	8105-448-009	220	0.46
.500 x .500	8105-448-012	190	0.33
.631 x .200	8106-448-015	80	0.25
.631 x .200	8106-448-019	80	0.25
.750 x .500	8107-448-011	345	0.58
.750 x .200	8107-448-012	190	0.33
.750 x .200	8107-448-025	190	0.33
1.000 x 1.000	8110-448-015	225	0.43
1.000 x .500	8110-448-016	395	0.77
1.000 x .250	8110-448-017	335	0.64
1.000 x .250	8110-448-018	335	0.64
1.150 x .200	8111-448-004	240	0.59
1.500 x .500	8115-448-006	1290	0.65
1.500 x .500	8115-448-007	1290	0.65
1.500 x 1.000	8115-448-011	825	0.49
1.500 x .250	8115-448-012	405	0.62
1.500 x .500	8115-448-029	1290	0.65
1.500 x 1.000	8115-448-032	825	0.49
1.500 X 2.000	8115-448-059	760	0.40
2.000 x .500	8120-448-006	1915	0.26
2.000 x .500	8120-448-007	1915	0.26
2.000 x 1.000	8120-448-019	2195	0.30
2.250 x .500	8122-448-003	1930	0.51
2.250 x .500	8122-448-008	1930	0.51
2.500 x 1.000	8125-448-004	2690	0.51
2.500 x .500	8125-448-006	2120	0.40
2.500 x .500	8125-448-015	2120	0.40
3.000 x .660	8130-448-004	3800	0.34
3.000 x .660	8130-448-010	3800	0.34

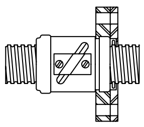
STEP FOUR: Complete Installation of the Wiper Kit

If applicable, complete wiper kit installation.

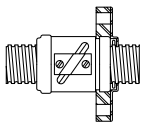
Wiper with Flange Retainer



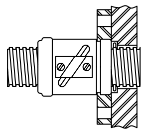
Wiper without Flange Retainer



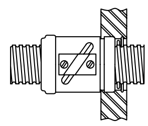
COUNTERBORED FLANGE ADAPTER PLATE



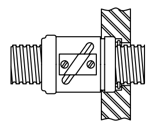
STAMPED FLANGE RETAINER PLATE



COUNTERBORED WORK PIECE FOR FLANGE ATTACHMENT



THREADED WORK PIECE FOR BALL NUT ATTACHMENT WITH SNAP RING RETAINER



THREADED WORK PIECE FOR BALL NUT ATTACHMENT

Installation

STEP FIVE: Lubricate the Ball Nut and Screw

Lubrication

Ball screw components are coated with a light oil for shipping and storage and must be properly lubricated upon assembly.

We recommend using TriGEL-450R or TriGEL-1800RC for lubricating ball screws every 500,000 to 1 million inches of travel or every six months. Other lubricants may be applicable but have not been evaluated.

The TriGEL grease can be applied directly to the screw threads near the root of the ball track. Some ball nut sizes are available with threaded lube holes for mounting lubrication fittings. For these ball nuts, the TriGEL grease can be pumped directly into the nut. Please refer to the catalog to verify which ball nuts have the threaded lube holes. It is recommended to use these nuts in conjunction with a wiper kit to contain the lubricant within the body of the nut.

Ball screws may require lubrication more frequently than 500,000 inches depending on both environmental and operating conditions. If the lubricant appears to be dispersed before this point or has become dry or crusted, the maintenance interval should be reduced. Before adding additional lubrication, wipe the screw clean, removing the old grease and any particular contamination seen on the screw.

Initial Lubrication

As with ball bearings, ball screws can be lubricated using either oils, greases or solid lubricants. Oils are recommended for systems which operate at high speeds, in aggressive environments, or in high ambient temperatures. Greases are recommended for ball screws where an oil circulation lubrication system cannot be applied, or areas where a lubricated-for-life situation is possible. Solid lubricants are typically applied to adverse operating conditions where oils and greases are not suitable.

Grease Lubrication Quantity

The nut can be filled to as much as 70% but no lower than 30% of its free space, depending upon operating speed and nDm. Nuts which are not fitted with wipers can be filled completely.

Grease Relubrication

In general, ball screws should be relubricated every 500,000 revolutions or every six months. Ball screws which operate above 70°C should be relubricated more often (1/2 the relubrication period for every 15°C increment above 70°C). Use of synthetic lubricants can increase the relubrication interval up to four times, depending on formulation and operating conditions.

Relubrication quantities should equal 30% of the nut free space. When possible, relubrication should be performed while the screw is operating.

Run-In

In order to distribute the grease throughout the ball screw elements, it is recommended that the screw be run two to ten times over its complete operating stroke. Run-in should be performed at initial start-up and after every subsequent relubrication.

Grease Operating Life

When relubricated with the proper frequency, ball screws should achieve their rated fatigue life. When no relubrication is possible, actual grease operating life will be affected by operating speed, running temperature, and the extent of environmental contamination.

Relubrication intervals can best be determined by experience. Changes in grease consistency, grease color, operating torque and operating temperature can indicate the need for lubrication replenishment.

Installation

STEP SIX: Install Ball Screw Assembly into Your Machine

Installation of Ball Screw Assembly

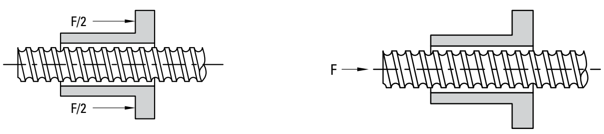
A ball nut flange is the recommended means of attaching a ball nut to a load. The ball screw assembly should be mounted into a system or machine as shown in the figures below. Axial loading of the nut is optimal for performance and life and side loading installations or applications should be avoided.

Typical ball screw installations are combined with linear slides to provide support and guidance. Linear rails and ball screws must then be aligned parallel to prevent binding, increased system torque and a decrease in life. Typical installation practice consists of "floating" the ball screw or the linear rail into alignment. To "float" a screw into alignment, secure the linear rail into position and adjust the mounting blocks or nut to minimize the error from parallel.

Nut Loading

Axial loading (on nut or screw) is optimal for performance and life. For applications requiring radial loads, please contact us.

Axial Loading: optimal

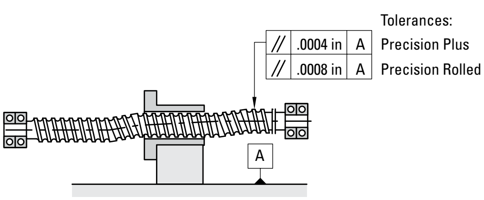


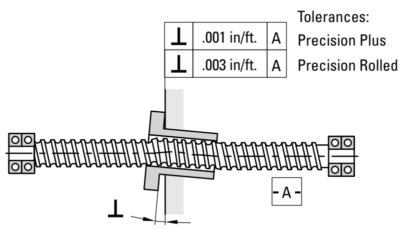
Radial Loading: detrimental*

* Minimize radial loading to less than 5% of the axial load.

Nut Mounting (Inch)

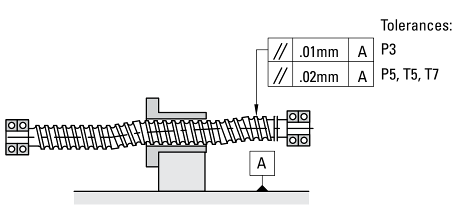
Use the following guidelines to achieve optimal performance.

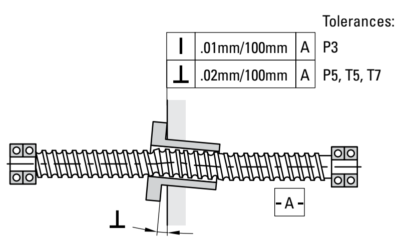




Nut Mounting (Metric)

Use the following guidelines to achieve optimal performance.
(All units are mm)





Maintenance and Service

If proper attention is paid to ball bearing screw selection and installation, virtually no maintenance will be required except for routine lubrication.

All Thomson ball screw assemblies are designed for maximum life and trouble-free operation when adequately serviced and maintained. Ball screw disassembly should be attempted only after complying with the general inspection and maintenance instructions outlined in this section. Be positive that the ball screw is at fault. Disassembly should be done only by persons familiar with ball screw assembly principles. In any unusual circumstances, contact Thomson.

Troubleshooting

Misalignment is one of the most common problems. Evidence of misalignment can generally be detected by one of the following situations:

- Squealing noise caused by the balls sliding in one or more of the circuits.
- Roughness in the form of vibrations or slightly erratic operation. This can normally be detected by "feel" when placing your hand on the return circuits.
- Excessive heat at the ball nut. Any appreciable temperature above the ambient of adjacent components should be considered excessive.

Gouging or scoring marks on the ball contact area of the screw may be caused by trapped balls between the circuits, broken balls, broken pick-up fingers or deflectors, or foreign objects which may have been digested by the ball nut.

When any of these conditions are encountered, examine the installation and, if necessary, immediately take corrective action to eliminate the cause and prevent further damage.

General Inspection of the Screw Shaft

Inspect the shaft ball grooves for signs of excessive wear, pitting, gouges, corrosion, or brinelling. Normally, where any of these conditions exist on most Thomson Precision units, it may be more economical and advisable to replace the screw shaft.

Backlash

Secure the screw shaft rigidly in a table clamp or similar device. Make sure it cannot rotate. Push firmly on the ball nut, first in one direction, then in the opposite direction. The axial movement of the ball nut is the backlash. This measurement can be taken with a dial indicator. Make sure that neither member rotates while the readings are taken.

Backlash with the following limits is considered acceptable:

Ball Diameter	Max. Permissible† Lash (used unit)	Max. Lash (new unit)
0 - 1/8"	.008	.005
5/32" - 1/4"	.014	.007
9/32" - 15/32"	.025	.010
1/2" and up	.050	.015

† Values based on wear resulting from foreign material contamination and/or lack of lubrication.

If, after inspection, the screw shaft appears to be usable but has excessive backlash, proceed with further disassembly and component inspection.

Disassembly

General Instructions: Have a clean container, such as a tote tray or cardboard box, handy for each ball return circuit of the ball nut assembly. A piece of clean cloth should be placed on the work table and gathered around the edge to form a pocket to retain the balls. Place the ball nut assembly over the cloth and remove the clamp.

Where more than one guide is held in place by a single clamp, secure each remaining guide with a strip of tape around the diameter of the ball nut to prevent accidental guide removal before you are ready for that circuit.

Remove both halves of the guide simultaneously to prevent distortion to either half. Catch all the balls from this circuit on the cloth by rotating the screw or ball nut slowly. Place the removed components into a container. Identify the container, the guide, and the circuit of the ball nut so the components can be reassembled in the same circuit from which they were removed. Repeat for each circuit.

Maintenance and Service

General Description

A Thomson ball screw is a force and motion transfer device belonging to the family of power transmission screws. It replaces sliding friction of the conventional power screw with the rolling friction of bearing balls. The balls circulate in hardened steel races formed by concave helical grooves in the screw and nut. All reactive loads between the screw and nut are carried by the balls which provide the only physical contact between these members.

As the screw and the nut rotate relative to each other, the balls are diverted from one end and carried by ball guides to the opposite end of the nut. This recirculation permits unrestricted travel of the nut in relation to the screw.

Method I: Ball nuts using a deflector return system are identified by threaded deflector studs extending through holes in the nut and the guide clamp. Lock nuts on the deflector studs are used to secure the clamps that hold the guides in place.

Method II: Ball nuts with pick-up fingers are identified by the finger projections integral with the guide. In this method, capscrew fasteners are used to fasten the clamp that holds the guide in place.

Pick-up Finger Method: Refer to the Component Inspection section.

Deflector Method: To remove the deflectors from the ball nut assembly, remove the ball nut from the screw shaft. The ball nut must be rotated since the deflectors engage loosely in the screw ball grooves and act as a thread. The deflectors now can be removed from the opposite ends of the ball nut so that you can use them for reference during component inspection.

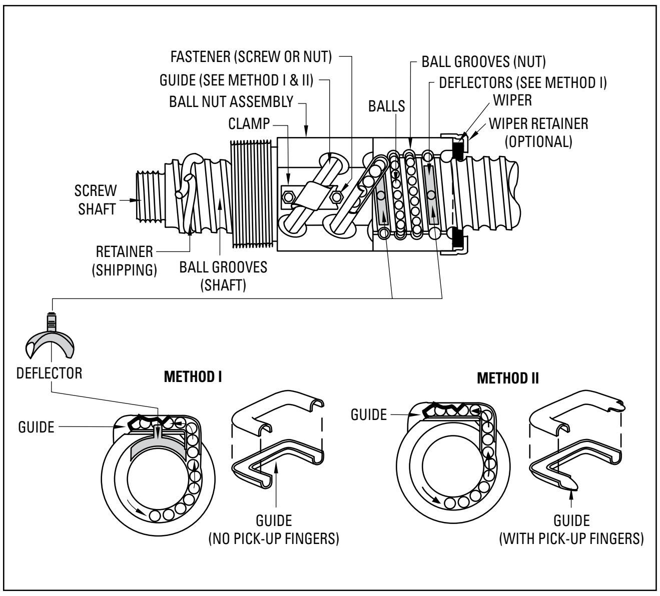


Figure 17

Maintenance and Service

Component Inspection and Replacement

Balls: If there is more than one circuit in the ball nut, count the balls in each of the separate containers to be sure each has the same number (within a variation of three balls). Check random samples (about 1/4 of the balls for a circuit) for the following:

- True roundness, with a .0001 in. maximum variation.
- Signs of scuffing or fish scaling.
- More than .0001 in. diameter variation between balls of the same circuit.

Where the random sampling shows balls out of round, signs of scuffing or variation of diameter in excess of .0001 in., or short count in any circuit, all balls in the unit must be replaced with a complete set of new balls. Ball kits are available from Thomson.

To ensure proper operation and long life of the serviced assembly, it is imperative that the diameters of all the replacement balls do not vary in excess of .00005 in. If Thomson kits are not used for service, make sure the balls meet the above specification. (Note: Use only chrome alloy steel balls, Grade 25 or better. Carburized balls or carbon steel balls will not provide adequate life.) See Ball Chart table.

Deflectors: Examine the ends of the deflectors for wear or brinelling. Wear can be determined by comparison with the unused ends of the two outside deflectors. Since these ends have not been subjected to wear from balls, they are in a like-new condition. Where wear or brinelling is evident, it is best to replace the deflectors with new ones.

Pick-up Fingers: Inspect the pick-up fingers, which consist of short extensions at the end of the guides. Replace with new guides if a ball brinell impression appears on the tip. Remove any burrs on the fingers. If the guides were distorted during removal, replace with new guides.

Ball Nut: Inspect the internal threads of the ball nut for signs of excessive wear, pitting, gouges, corrosion, spalling, or brinelling in the ball groove area. On large ball nuts, running the tip of your finger along the groove which is accessible will enable you to detect a secondary ridge in the ball groove area when wear is excessive or brinelling has occurred. (The extended lead of a mechanical pencil can also be used as a groove probe.) If inspection indicates any of these flaws, the ball nut assembly should be replaced.

Wipers: Prolonged use and environmental conditions will generally determine the condition of wipers. After cleaning wipers, reassemble over the screw shaft to determine whether a snug fit is maintained over the complete contour of the screw shaft. Any loose fitting or worn wipers should be replaced. Wiper kits are available for Thomson ball screws.

Note: If the assemblies have had extended use, it is recommended that all low cost items be replaced with new parts (i.e., balls, guides, deflectors, clamps). These can be ordered by simply referring to the assembly part number purchased.

Reassembly

Cleaning: Clean all components with a commercial solvent and dry thoroughly before reassembly.

Deflector Method: Where the ball nut is equipped with deflectors, install these and secure temporarily by running the lock nuts down the studs and tightening.

General Instructions: Position the ball nut on the screw shaft. Ball nuts with deflectors have to be screwed on. Other ball nuts will slide on.

Using dowels with an O.D. approximately equal to the diameter of the balls, center the ball nut grooves with the shaft grooves by inserting dowels into each of the ball nut return circuit holes.

Remove the second dowel from one end. With the ball return holes up, fill the circuit with balls from the container corresponding to that circuit. Turning the screw in the ball nut will help to feed the balls into the groove. When the circuit is full, the balls will begin to lift the end dowel from its position. To be sure there are no voids, lightly tap the top bearing ball and see if the end dowel moves.

The remaining ball in the container should fit into one of the halves of the return guide with space for about three to six left.

Note: There must be some free space in the ball circuit so the balls will roll and not skid. Do not try to add extra balls into the circuit.

Place a dab of bearing grease at each end of the half return guide to hold the balls in place. Now, take the other half of the return guide and place it over the half guide you have filled with balls and insert two ends of the ball guide into the respective hole in the ball nut. Seat by tapping gently with a rawhide or plastic mallet.

Note: Where more than one ball circuit must be filled in the ball nut, tape the ball return circuit to the ball nut to prevent accidental removal. Repeat the filling procedure for the remaining circuits.

With all ball circuits filled and all return guides in place, secure the return guides with the retaining clamp.

CAUTION: Care should be taken to ensure that balls are not accidentally trapped between circuits in units having pick-up fingers. In deflector units, the deflectors will fill this space.

Inspection: Wrap tape around the ball grooves at the ends of the screw shaft to prevent the ball nut from rolling off. Now inspect the assembly for free movement of the ball nut along the entire stroke. There should be no binding, squeal, or roughness at any point.

Reducing Backlash: Backlash can be reduced by replacing all the balls with a larger size. If the diameters of the bearing balls are increased by .001 in., backlash is decreased by .003 in. (Ball kits are available for these applications.)

Maintenance and Service

Ball Chart (Grade 25 or Better)

Size (Inches)	Part Number	Nominal Diameter (Inch)	Number of Balls
0.375 x 0.125	**8103-448-003**	0.078	108
0.375 x 0.125	**8103-448-013**	0.078	108
0.375 x 0.125	**8103-448-017**	0.078	49
0.375 x 0.125	**8103-448-018**	0.078	49
0.500 x 0.200	**8105-448-023**	0.125	46
0.500 x 0.200	**8105-448-013**	0.125	96
0.500 x 0.200	**8105-448-008**	0.125	192
0.500 x 0.500	**8105-448-014**	0.125	108
0.500 x 0.500	**8105-448-011**	0.125	146
0.500 x 0.500	**8105-448-016**	0.125	146
0.631 x 0.200	**8106-448-022**	0.125	68
0.631 x 0.200	**8106-448-026**	0.125	68
0.631 x 0.200	**8106-448-045**	0.125	67
0.631 x 0.200	**8106-448-009**	0.125	70
0.631 x 0.200	**8106-448-008**	0.125	70
0.631 x 0.200	**8106-448-015**	0.125	140
0.631 x 0.200	**8106-448-019**	0.125	140
0.631 x 0.200	**8106-448-012**	0.125	140
0.631 x 0.200	**8106-448-036**	0.125	136
0.631 x 0.200	**8106-448-036**	0.125	136
0.631 x 10.000	**8106-448-037**	0.125	74
0.631 x 10.000	**8106-448-041**	0.125	46
0.631 x 10.000	**8106-448-042**	0.125	92
0.750 x 0.200	**8107-448-018**	0.125	86
0.750 x 0.200	**8107-448-026**	0.125	86
0.750 x 0.200	**8107-448-047**	0.125	86
0.750 x 0.200	**8107-448-016**	0.125	86
0.750 x 0.200	**8107-448-027**	0.125	172
0.750 x 0.200	**8107-448-046**	0.125	172
0.750 x 0.200	**8107-448-025**	0.125	172
0.750 x 0.500	**8107-448-014**	0.156	152
0.750 x 0.500	**8107-448-020**	0.156	152
0.750 x 0.500	**8107-448-049**	0.156	152
0.750 x 0.500	**8107-448-048**	0.156	152
0.750 x 0.500	**8107-448-011**	0.156	304
0.875 x 0.200	**8109-448-001**	0.125	184
0.875 x 0.200	**8109-448-003**	0.125	168
1.000 x 0.250	**8110-448-091**	0.156	86
1.000 x 0.250	**8110-448-055**	0.156	86
1.000 x 0.250	**8110-448-032**	0.156	89
1.000 x 0.250	**8110-448-030**	0.156	89
1.000 x 0.250	**8110-448-056**	0.156	171
1.000 x 0.250	**8110-448-026**	0.156	182
1.000 x 0.250	**8110-448-024**	0.156	182
1.000 x 0.250	**8110-448-087**	0.156	182
1.000 x 0.250	**8110-448-088**	0.156	182
1.000 x 0.250	**8110-448-017**	0.156	182
1.000 x 0.250	**8110-448-100**	0.156	86
1.000 x 0.500	**8110-448-022**	0.156	196
1.000 x 0.500	**8110-448-016**	0.156	392
1.000 x 1.000	**8110-448-086**	0.156	100
1.000 x 1.000	**8110-448-020**	0.156	107
1.000 x 1.000	**8110-448-034**	0.156	107

Size (Inches)	Part Number	Nominal Diameter (Inch)	Number of Balls
1.150 x 0.200	**8111-448-006**	0.125	252
1.150 x 0.200	**8111-448-004**	0.125	504
1.171 x 0.413	**8111-448-015**	0.281	60
1.500 x 0.250	**8111-448-083**	0.156	260
1.500 x 0.250	**8111-448-020**	0.156	260
1.500 x 0.250	**8111-448-012**	0.156	560
1.500 x 0.473	**8111-448-081**	0.344	86
1.500 x 0.500	**8115-448-016**	0.312	140
1.500 x 0.500	**8115-448-018**	0.312	140
1.500 x 0.500	**8115-448-006**	0.312	280
1.500 x 1.000	**8115-448-014**	0.344	68
1.500 x 1.000	**8115-448-080**	0.344	60
1.500 x 1.000	**8115-448-011**	0.344	136
1.500 x 1.000	**8115-448-049**	0.344	68
1.500 x 1.875	**8115-448-082**	0.281	83
1.500 x 1.875	**8115-448-087**	0.281	168
1.500 x 2.000	**8115-448-056**	0.281	96
1.500 x 2.000	**8115-448-057**	0.281	96
2.000 x 0.500	**8120-448-011**	0.375	150
2.000 x 0.500	**8120-448-013**	0.375	150
2.000 x 0.500	**8120-448-006**	0.375	300
2.000 x 0.500	**8120-448-007**	0.375	300
2.000 x 1.000	**8120-448-021**	0.375	160
2.000 x 1.000	**8120-448-019**	0.375	320
2.250 x 0.500	**8122-448-005**	0.374	170
2.250 x 0.500	**8122-448-007**	0.374	154
2.500 x 1.000	**8122-448-006**	0.375	164
2.500 x 0.250	**8125-448-021**	0.156	468
2.500 x 0.500	**8125-448-010**	0.375	184
2.500 x 1.000	**8125-448-008**	0.375	194
3.000 x 0.660	**8130-448-007**	0.500	186
3.000 x 1.500	**8130-448-018**	0.625	186
4.000 x 1.000	**8140-448-001**	0.623	186
.625 x 3	**5707445 / 7828128**	0.187	60
.625 x 6	**5708943 / 7828129**	0.187	120
1.000 x 3	**5707472 / 7828130**	0.187	78
1.000 x 6	**5708944 / 7828131**	0.187	156
1.500 x 3	**5707528 / 7828132**	0.250	84
1.500 x 6	**5708945 / 7828133**	0.250	168
2.000 x 3	**5707530 / 7828134**	0.312	72
2.000 x 6	**5708946 / 7828135**	0.312	144
2.500 x 3	**5707532 / 7828136**	0.375	66
2.500 x 6	**5708947 / 7828137**	0.375	132
4.062 x 6	**5708330 / 7828138**	0.375	180

Maintenance and Service

Size (mm)	Part Number	Nominal Diameter (mm)	Number of Balls
16 x 5	**KGF-D-1605-RH-KK**	3.500	42
20 x 5	**KGF-D-2005-RH-KK**	3.500	54
20 x 20	**KGF-D-2020-RH-KK**	3.500	100
25 x 5	**KGF-D-2505-RH-KK**	3.500	66
25 x 10	**KGF-D-2510-RH-KK**	3.500	164
25 x 25	**KGF-D-2525-RH-KK**	3.500	120
32 x 5	**KGF-D-3205-RH-KK**	3.500	116
32 x 10	**KGF-D-3210-RH-KK**	5.556	54
32 x 20	**KGF-D-3220-RH-KK**	5.556	136
32 x 32	**KGF-D-3232-RH-KK**	3.969	124
40 x 5	**KGF-D-4005-RH-KK**	3.500	180
40 x 10	**KGF-D-4010-RH-KK**	7.144	72
40 x 20	**KGF-D-4020-RH-KK**	5.556	156
40 x 40	**KGF-D-4040-RH-KK**	7.144	96
50 x 10	**KGF-D-5010-RH-KK**	7.144	88
50 x 20	**KGF-D-5020-RH-KK**	6.350	164
63 x 10	**KGF-D-6310-RH-KK**	7.144	140
63 x 20	**KGF-D-6320-RH-KK**	7.144	186
80 x 10	**KGF-D-8010-RH-KK**	7.144	210
16 x 5	**KGF-L-1605-RH-E-KK**	3.500	56
20 x 5	**KGF-L-2005-RH-E-KK**	3.500	108
25 x 5	**KGF-L-2505-RH-E-KK**	3.500	132
32 x 5	**KGF-L-3205-RH-E-KK**	3.500	232
32 x 10	**KGF-L-3210-RH-E-KK**	5.500	108
40 x 5	**KGF-L-4005-RH-E-KK**	3.500	360
40 x 10	**KGF-L-4010-RH-E-KK**	6.350	160
50 x 10	**KGF-L-5010-RH-E-KK**	7.144	176
63 x 10	**KGF-L-6319-RH-E-KK**	7.144	280
80 x 10	**KGF-L-8010-RH-E-KK**	7.144	420
16 x 5	**7106-448-061**	3.500	45
16 x 10	**7106-448-062**	3.000	102
20 x 5	**7107-448-063**	3.500	48
25 x 5	**7110-448-064**	3.500	63
25 x 10	**7110-448-065**	3.500	75
25 x 20	**7110-448-066**	3.500	80
25 x 25	**7110-448-067**	3.500	130
25 x 50	**7110-448-068**	3.500	130
32 x 5	**7112-448-069**	3.500	140
32 x 10	**7112-448-070**	7.140	42
32 x 20	**7112-448-071**	5.000	84
32 x 32	**7112-448-072**	3.969	124
40 x 5	**7115-448-073**	3.500	180
40 x 10	**7115-448-074**	7.140	54
40 x 20	**7115-448-075**	5.000	104
40 x 40	**7115-448-076**	3.500	360
50 x 10	**7120-448-077**	7.140	115
50 x 20	**7120-448-078**	7.140	100
63 x 10	**7125-448-001**	7.144	140
63 x 20	**7125-448-002**	7.140	96

Size (mm)	Part Number	Nominal Diameter (mm)	Number of Balls
16 x 5	**KGF-N-1605-RH-EE**	3.500	45
20 x 5	**KGF-N-2005-RH-EE**	3.500	48
20 x 20	**KGF-N-2020-RH-EE**	3.500	100
20 x 50	**KGF-N-2050-RH-EE**	3.500	140
25 x 5	**KGF-N-2505-RH-EE**	3.500	63
32 x 5	**KGF-N-3205-RH-EE**	3.500	140
32 x 10	**KGF-N-3210-RH-EE**	7.140	42
32 x 40	**KGF-N-3240-RH-EE**	3.500	168
40 x 5	**KGF-N-4005-RH-EE**	3.500	180
40 x 10	**KGF-N-4010-RH-EE**	7.140	54
50 x 10	**KGF-N-5010-RH-EE**	7.140	115
63 x 10	**KGF-N-6310-RH-EE**	7.140	140
80 x 10	**KGF-D-8010-RH-EE**	7.144	175
12 x 10	**KGM-D-1210-RH-EE**	2.000	63
16 x 5	**KGM-D-1605-RH-EE**	3.500	45
16 x 10	**KGM-D-1610-RH-EE**	3.000	102
20 x 5	**KGM-D-2005-RH-EE**	3.500	48
25 x 5	**KGM-D-2505-RH-EE**	3.500	63
25 x 10	**KGM-D-2510-RH-EE**	3.500	75
25 x 20	**KGM-D-2520-RH-EE**	3.500	80
25 x 25	**KGM-D-2525-RH-EE**	3.500	130
25 x 50	**KGM-D-2550-RH-EE**	3.500	130
32 x 5	**KGM-D-3205-RH-EE**	3.500	140
40 x 5	**KGM-D-4005-RH-EE**	3.500	180
40 x 10	**KGM-D-4010-RH-EE**	7.140	54
40 x 20	**KGM-D-4020-RH-EE**	5.000	104
40 x 40	**KGM-D-4040-RH-EE**	3.500	360
50 x 10	**KGM-D-5010-RH-EE**	7.144	155
63 x 10	**KGM-D-6310-RH-EE**	7.144	140
63 x 20	**KGM-D-6320-RH-EE**	7.140	96
12 x 5	**KGM-N-1205-RH-OO**	2.000	60
20 x 5	**KGM-N-2005-RH-EE**	3.500	48
20 x 20	**KGM-N-2020-RH-EE**	3.500	100
20 x 50	**KGM-N-2050-RH-EE**	3.500	140
25 x 5	**KGM-N-2505-RH-EE**	3.500	63
32 x 5	**KGM-N-3205-RH-EE**	3.500	140
32 x 10	**KGM-N-3210-RH-EE**	7.140	42
32 x 20	**KGM-N-3220-RH-EE**	5.000	84
32 x 40	**KGM-N-3240-RH-EE**	3.500	168
40 x 5	**KGM-N-4005-RH-EE**	3.500	180
50 x 10	**KGM-N-5010-RH-EE**	7.140	115
50 x 20	**KGM-N-5020-RH-EE**	7.140	100
63 x 10	**KGM-D-6310-RH-EE**	7.144	140
80 x 10	**KGM-D-8010-RH-EE**	7.144	175
12 x 4	**KGM-G-1204-RH-00**	1.984	57
16 x 5	**KGF-D-1605-RH-KK**	3.500	56
20 x 5	**KGM-G-2005-RH-KK**	3.500	72
25 x 5	**KGM-G-2505-RH-KK**	3.500	110
25 x 10	**KGM-G-2510-RH-KK**	3.500	55
32 x 5	**KGM-G-3205-RH-KK**	3.500	145
32 x 10	**KGM-G-3210-RH-KK**	5.556	72
40 x 5	**KGM-G-4005-RH-KK**	3.500	180
40 x 10	**KGM-G-4010-RH-KK**	7.144	90
40 x 20	**KGM-G-4020-RH-KK**	5.556	80
50 x 10	**KGM-G-5010-RH-KK**	7.144	132
63 x 10	**KGM-G-6310-RH-KK**	7.144	168
80 x 10	**KGM-G-8010-RH-KK**	7.144	210

Maintenance and Service

Inspection and Existing Preload Check: Whenever possible, the complete ball screw assembly should be removed from the machine prior to a thorough inspection. Preliminary screw inspection can be made while the unit is still in the machine. Preload can be determined by measuring movement of the nut in respect to the screw shaft. Clamp an indicator to the screw shaft with its probe resting on the face of the nut. Apply a load to the machine carriage in both directions. Be sure that the screw cannot rotate or move axially. Any measurable backlash between the ball nut and screw is an indication that preload does not exist. (See Figure 18.)

If no backlash exists, proceed further as outlined to determine whether proper preload remains in the unit. Existing preload, Wp, can be determined by measuring torque, Tp, using the following formula:

$$Wp = \frac{Tp}{.007}$$

where: Wp = Preload force, in lb.
Tp = Torque, in lb-in. (due to preload only)

Note: The above check is to determine preload only, and does not take into account torque due to seal drag or operating load.

Torque can be measured by means of a spring scale mounted to any projection on the ball nut or by means of a lever or rod secured to the ball nut. In taking this measurement, be sure the exact lever arm distance is measured. (See Figure 18.) This measurement (inch) multiplied by the scale reading (lb.) equals Tp (torque lb-in.). Existing preload can now be determined using the above formula.

Preload adjustment of a Precision ball screw (Figure 18) requires no disassembly. Possible removal of the ball nut from the machine housing may be necessary to expose the adjusting nut.

Disassembly: If in doubt about disassembly of preloaded ball nuts, contact Thomson Application Engineering. If the unit is to be disassembled for general repair, follow the steps previously outlined in this section.

If being disassembled for preload adjustment, follow the guidelines except remove only one-half of the ball nut assembly to an arbor. If a standard arbor is not available, one can be made from a piece of shafting or tubing with a diameter approximately .005 inch less than the root diameter of the ball grooves in the screw shaft. Both halves of the ball nut will come apart as soon as the last ball in the nut is free of the grooves in the screw shaft. It is not necessary to remove the other half from the screw.

Preload Adjustment: The adjusting nut unit in Figure 18 can be adjusted to the desired preload with the use of additional shims. To make further adjustment, loosen the set screw lock located on the periphery of the lock nut. Use a spanner wrench to rotate the adjusting nut to the desired setting. Recheck the preload.

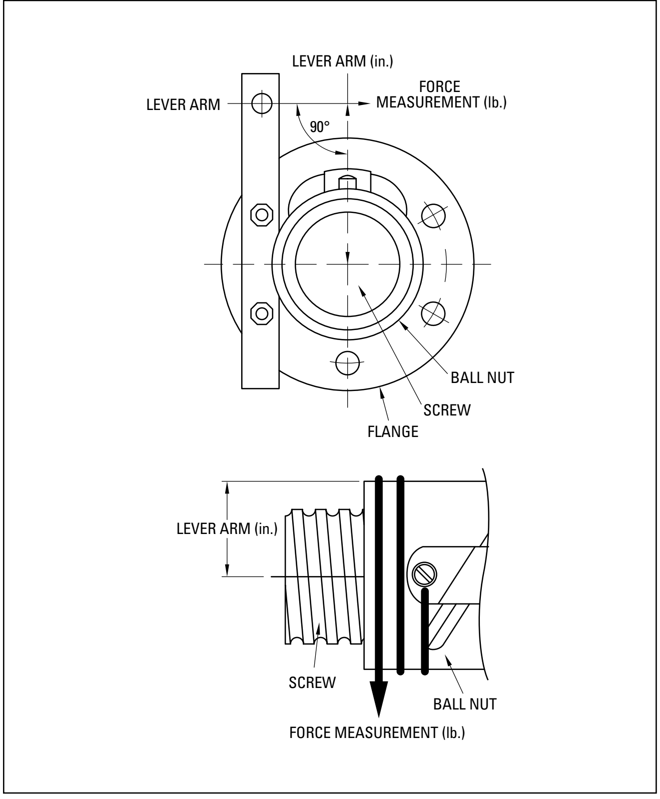


Figure 18

For all other standard units in Figure 18, a shim increase of .001 inch will, as a general rule, increase preload by 500 to 1,000 lb. This varies depending upon screw size; therefore, some judgement and trial and error may be necessary before the desired preload is achieved.

Preload force, Wp, can be determined by measuring torque, Tp, after the desired preload has been established using the following formula:

$$Tp = .007 \times Wp$$

where: Tp = torque, lb-in. (due to preload only)
Wp = preload force, lb.

This section is intended to provide basic necessary information to properly service and maintain Thomson ball screws. Other forms of preloaded units may be encountered which have been designed for particular applications. Please contact Thomson Application Engineering for other specific information.

Lubrication

Guidelines

Ball screws must be lubricated to operate properly and achieve the rated life. We recommend using TriGEL-450R or TriGEL-1800RC for lubricating ball screws. Other oils and greases may be applicable but have not been evaluated.

The TriGEL® grease can be applied directly to the screw threads near the root of the ball track. Some ball nut sizes are available with threaded lube holes for mounting lubrication fittings. For these ball nuts, the TriGEL grease can be pumped directly into the nut. Please refer to the catalog detail views to verify which ball nuts have the threaded lube holes. It is recommended to use these nuts in conjunction with a wiper kit to contain the lubricant in the body of the nut.

Lubrication

Inspection Prior to Lubrication: All ball screw assemblies should run smoothly throughout the entire stroke. If the torque is not uniform over the entire stroke:

- Visually inspect the screw shaft for accumulations of foreign matter.
- Using cleaning fluid or solvent, remove dirt from the ball grooves. Be sure to flush the ball nut assembly thoroughly.
- Cycle the ball nut along the screw shaft several times. Wipe with a dry, lintless cloth and lubricate immediately.
- If the assembly continues to operate erratically after cleaning, contact Thomson for further instructions.

Lubrication: The operating environment primarily determines the frequency and type of lubrication required by ball screws. The screw shaft should be inspected frequently and lubricated as required by the environmental conditions present. Lubricants can vary from instrument grade oil for dirty and heavy-dust environments to a good grade ball bearing grease for protected or clean environments. For most applications, a good 10W30 oil periodically wiped on the screw shaft with a damp cloth or applied by a drip or mist lubricator will suffice.

CAUTION: Where the screw is unprotected from airborne dirt, dust, etc., do not leave a heavy film of lubricant on the screw. Keep the screw shaft barely damp with lubricant. Inspect at regular intervals to be certain lubricating film is present. Where the application requires operation at temperatures below 0° F, an instrument grade oil is recommended. Operating environments from 0° F to 180° F will require a good grade 10W30 oil. For assemblies with balls larger than 3/8 in. diameter, MIL G 3278 grease is recommended. Bearing grease is recommended for operating environments at nominally higher temperatures. Again, in unprotected conditions, the lubricant is best applied with a lubricant-dampened cloth, taking care not to leave an excessive film thickness on the screw. Ball screws should never be run dry.

Lubrication Selection Chart for Ball & Lead Screw Assemblies

Thomson Gel Type	TriGel-300S	TriGel-450R	TriGel-600SM	TriGel-1200SC	TriGel-1800RC
Application	Acme Screws Supernuts, Plastic Nuts	Ball Screws, Linear Bearings	Bronze Nuts	Acme Plastic Nuts, Clean Room, High Vacuum	Ball Screws, Linear Bearings, Bronze Nuts, Clean Room, Vacuum
Maximum Temperature*	200°C (392°F)	125°C (257°F)	125°C (257°F)	250°C (482°F)	125°C (257°F)
Mechanism Materials	Plastic on Plastic or Metal	Metal on Metal	Metal on Metal Bronze on Steel	Plastic or Metals, Combination	Metal on Metal
Mechanical Load	Light	Moderate	Moderate to Heavy	Light to Moderate	Moderate
Very Low Torque Variation over Temperature	Yes	—	—	Yes	—
Very Low Starting Torque	Yes	Yes	—	Yes	Yes
Compatibility with Reactive Chemicals	Not recommended w/o OEM testing	Not recommended w/o OEM testing	Not recommended w/o OEM testing	Usually OK	Not recommended w/o OEM testing
Compatibility with Plastics and Elastomers	May cause silicon rubber seals to swell	May cause EPDM seals to swell	May cause EPDM seals to swell	Usually OK	May cause EPDM seals to swell
Clean Room Use	Not recommended	Not recommended	Not recommended	Usually OK	Usually OK
High Vacuum Use	Not recommended	Not recommended	Not recommended	Usually OK	Usually OK
Vapor Pressure (25°C)	Varies with lot	Varies with lot	Varies with lot	$8x10^{-9}$ torr	$4x10^{-9}$ torr
Order Number					
10cc Syringe	TriGel-300S	TriGel-450R	NA	TriGel-1200SC	TriGel-1800RC
1 Pound Tube	TriGel-300S-1	TriGel-450R-1	NA	NA	NA
4oz Tube	NA	NA	TriGel-600SM	NA	NA

* Maximum temperature for continuous exposure. Higher surge temperatures may be permissible but should be validated in the actual end use by the OEM. Low temperature limits are -15°C or lower. Consult Thomson for specifics.

Glossary/Formulas

Accuracy
A measurement of precision. Perfect accuracy, for example, means advancing a ball nut 1 in. from any point on a screw will always require the exact same number of revolutions.

Annealed Ends
A manufacturing process which removes brittleness while softening screw stock to allow for machining of end journals.

Arbor or Mandrel
Temporary shaft used to support ball nut during shipping assembly/disassembly.

Axial Lash/Backlash
The axial free motion between the ball nut and ball screw; a measure of system stiffness and repeatability.

Backdrive
Application of a force on a ball nut to cause rotation of the screw shaft; in essence, converting linear to rotary motion.

Ball Bearing Spline
A linear motion device using the rolling contact principle. In a spline, the path of the bearings is parallel to the shaft to allow axial freedom and to provide torque transmitting capacity.

Ball Circle Diameter
The distance between the centerlines of two exactly opposing recirculating balls when they are in contact with the screw. The basic point of reference used by Thomson when dealing with ball screws.

Ball Nut
A nut compatible with a ball screw. The nut contains a series of bearing balls which are carried from one end of the nut to the other by a return tube.

Ball Screw
A ball bearing screw is a screw that runs on bearing balls. The primary function of a ball bearing screw is to convert rotary motion to linear motion or torque to thrust.

Bearing Ball Circuit
The closed path of recirculating balls within the ball nut assembly. A multiple circuits has a greater load carrying capability than a single circuit ball nut assembly of the same.

Compression Load
Compression load is a load which would tend to compress or buckle the ball screw shaft.

Conformity Ratio
Ratio of the ball track radius to the ball diameter.

Contact Angle
Nominal angle between a plane perpendicular to the screw and a line drawn between a ball and the ball tracks and projected on a plane passing through the screw axis and the center of the ball. The angle at which the ball contacts the groove.

Column Load
Column loading is the compression load on the screw. This load has a tendency to buckle the screw and is dependent on screw diameter, screw length and type of mounting.

Critical Speed
The condition where the rotary speed of the assembly sets up harmonic vibrations. These vibrations are the result of shaft diameter, unsupported length, type of bearing support, ball nut mounting method, or the shaft or ball nut rpm. Vibrations may also be caused by a bent screw or faulty installation alignment.

Cycle
The complete forward and reverse motion of the screw (or nut) when moving the load. One cycle is equivalent to two load carrying strokes (one forward and one backward).

Diameter — Major
The outside diameter of the ball bearing screw shaft. In dealing with ball bearing screws, this is the basic measurement.

Diameter — Minor (Root)
Diameter of the screw measured at the bottom of the ball track.

Diameter — Pitch
The nominal diameter of a theoretical cylinder passing through the centers of the balls when they are in contact with the ball bearing screw and ball nut tracks.

Driving Torque
The amount of effort, measured in pound-inches, required to turn the ball screw and move the load.

Dynamic Load Rating
Dynamic load rating is the maximum load which a ball bearing screw assembly can maintain for 1.0 million inches of travel (Inch Series) or 1.0 million revolutions (Metric Series).

Efficiency
Expressed as a percentage, the ability of a ball screw assembly to convert torque to thrust with minimal mechanical loss. Thomson ball screws operate at over 90% efficiency.

End Bearing Support (End Fixity)
The three basic bearing configurations that are commonly used to support the ends of a ball screw are.

a) A single journal or ball type bearing (simple support).
b) A pair of back-to-back, angular contact bearings to control end play (simple support).
c) A pair of spaced bearings for added rigidity (rigid support)

Four combinations of bearing supports are used throughout this catalog for selection purposes.

Flange
A metal mounting plate attached to a ball nut.

Gothic (or Ogival) Groove
A ball track cross-section shaped like a Gothic arch.

Journal
1. A machined cylindrical surface.
2. End journals are machined ends of ball bearing screws which allow for bearing mounting.

Land Area
The area on the outside diameter of a ball bearing screw between ball grooves.

Lead
The axial distance a screw travels during one revolution.

Lead Error
The amount of positional error per foot (Inch Series) or per 300mm (Metric Series) that is inherent in linear motion on ball screws.

Glossary/Formulas

Lead Tolerance
The maximum variation from nominal, measured in inches per foot, cumulative.

Left (Right) Hand Threads
The direction of threads on a shaft or in a nut. Left hand means that the nut will move away if rotated counterclockwise. Right hand means the nut will move away if rotated clockwise.

Linear Expansion
Ball screw and spline inner races have a coefficient of linear expansion of 0.0000065 for each degree of change (F) and for each inch of race length.

Load Carrying Balls
The balls in contact with the ball grooves of both the nut and the screw for load carrying purposes.

Load/Life Rating
The usable life of a ball bearing screw assembly measured in inches of travel under a specific load. The length of travel that 90 percent of a group of ball bearing screws will complete, or exceed, before the first evidence of fatigue develops.

Lubrication
To provide the maximum useful life, ball splines and ball screws require lubrication. In general, standard ball bearing lubrication practices are acceptable.

Off Center Load (Eccentric)
A load tending to cock the ball nut on the screw, reducing the rated life. This must be considered in the selection of the ball screw assembly.

Operating Loads
The normal operating force in pounds (lb.) or Newtons (N) which the ball spline or ball screw will experience is considered the operating load. Contact us for assistance in applications subject to widely fluctuating loads or to optimize design.

Preload
The use of one group of bearing balls set in opposition to another to remove axial lash or backlash and increase ball bearing screw stiffness. All axial backlash is eliminated in preloading.

Protective Coatings
Standard outer races are supplied with a black oxide coating. Inner races are furnished with a phosphate coating. Contact Application Engineering for additional options.

Repeatability
A measure of constancy that is directly related to axial backlash. Higher backlash equates to lower repeatability and may be corrected by preloading the ball nut if required.

Root Diameter
The diameter of the screw shaft as measured at the bottom of the ball track.

Screw Diameter (land diameter)
The outside diameter of the screw shaft.

Screw Starts
The integral number of independent threads on the screw shaft; typically one, two, or four.

Side Load (radial)
A load from the side that will reduce the rated life and must be considered in the selection of the ball bearing screw.

Spring Rate
A ratio of load versus deflection of a component or of a total system. System stiffness will always be less than its most compliant member. Thus, in any system where a ball screw is used and where high system stiffness is a primary design requirement, Thomson should be contacted for recommendations based on the specifics of the application.

Static Load
Static load is the maximum non-operating load capacity above which brinelling of the ball track occurs.

Straightness
The linearity of a screw shaft. Precision screw stock is .010 in/ft. with .040 inch max. Precision Plus stock is typically .003 inch over the entire length of the screw.

Stroke
The maximum length of extension of a ball nut on the screw shaft.

Temperature (operating)
With suitable lubricants, ball splines and ball screws will operate with a minimum loss of efficiency between temperatures of -65° to +300°F (-53° to +149°C). Contact our application engineers for assistance in applications with extreme temperatures.

Tension Load
Tension load is a load which would tend to stretch the ball screw shaft.

Thrust Load
Thrust load is loading parallel to and concentric with the centerline of the screw shaft which acts continuously in one direction. Thrust loading is the proper method of attaching the load to the ball bearing screw assembly.

Travel and Travel Rate
The distance a ball nut moves relative to the screw shaft. Travel rate is the distance traveled in a specific time period.

THOMSON
Linear Motion. Optimized.

Glossary/Formulas

Some Useful Formulas for Ball Screw Assemblies

Torque, Rotary to Linear

Rotating the screw to translate the nut, or rotating the nut to translate the screw.

Ball Screw Assemblies

$$\text{Torque (in lbs)} = .177 \times \text{Load (lbs)} \times \text{Lead (inches)}$$

Lead Screw Assemblies

$$\text{Torque (in lbs)} = \frac{\text{Load (lbs)} \times \text{Lead (inches)}}{2\pi \times \text{efficiency}^*}$$

* Acme screw efficiency is variable with the helix angle of the threads, the friction of the material and the finish. See the efficiency formula below.

Torque, Linear to Rotary

Translating the screw to rotate the nut, or translating the nut to rotate the screw.

Ball Screw Assemblies

$$\text{Torque (in lbs)} = .143 \times \text{Load (lbs)} \times \text{Lead (inches)}$$

Lead Screw Assemblies

$$\text{Torque (in lbs)} = \frac{\text{Load} \times \text{Lead} \times \text{Efficiency}}{2\pi}$$

The higher the lead of the screw the less effort required to backdrive either the screw or the nut.
As a rule, the lead of the screw should be more than 1/3 the diameter of the screw to satisfactorily backdrive.

Efficiency

Ball Screw Assemblies

Most ball screw assemblies are better than 90% efficient.

Lead Screw Assemblies

$$\%\ \text{Efficiency} = \frac{\tan(\text{helix angle})}{\tan(\text{helix angle} + \arctan f)} \times 100$$

f = coefficient of friction

Horsepower

Torque to Horsepower

$$hp = \frac{\text{Torque (in lbs)} \times \text{rpm}}{63{,}000}$$

Horsepower to Torque

$$\text{Torque} = \frac{63{,}000 \times hp}{\text{rpm}}$$

Column Load Strength*

(Based on Eulers Formula)

$$P_{cr} = \frac{1.405 \times 10^7 \times F_c \times d^4}{L^2}$$

P_{cr} = maximum loads (lbs)
F_c = end support factor
- .25 one end fixed, other free
- 1.00 both ends supported
- 2.00 one end fixed, other supported
- 4.00 both ends fixed

d = root diameter of screw (in.)
L = distance between nut and load carrying bearing (in.)

When possible, design for tension loads to eliminate the buckling factor and reduce the required screw size

* Formula only valid if $L/_d \geq 18.25$.

Critical Screw Shaft Speed

(Maximum rotational speed of screw)

$$C_s = F_c \times 4.76 \times 10^6 \times \frac{d}{L^2}$$

C_s = critical speed (rpm)
d = root diameter of screw (in.)
L = length between supports (in.)
F_c = end support factor
- .36 one end fixed, other free
- 1.00 both ends supported
- 1.47 one end fixed, other supported
- 2.23 both ends fixed

Critical shaft speed should be reduced to 80% to allow for other factors such as alignment and straightness

Custom Capabilities

The Thomson Advantage
In addition to our extensive standard ball and lead screw products, Thomson has designed and manufactured custom engineered products to fit the unique requirements of our customers. We welcome and encourage requests for specialized products, regardless of quantity or frequency of order. Our custom products range from one-time-only units to high quantity requirements. A few of our custom possibilities are listed below:

Custom Plastic Nuts
If cost or design constraints dictate a more integrated package, let our engineering staff help you simplify your design. We offer a full range of manufacturing capabilities from injection molding to CNC machining with the largest selection of engineering plastics to suit your applications and specifications.

- Our engineering staff will ensure your part is right the first time
- Full range of engineering plastics including internally lubricated and high temperature thermoplastics

Precision Screw Products
Thomson provides engineering support and quality assurance for all of its components and assemblies allowing our customers to focus on the larger design picture. Our full range of designs and sizes for our linear motion components allow greater design flexibility, while our support staff ensures proper initial application and comprehensive support once installed.

Components and Assemblies
From components to complete assemblies, Thomson always provides the highest performance products to your applications. Let us assist in your design to ensure proper operation of our components, or let us provide you a complete solution.

- Complete solutions to your linear motion designs with our industry tested assemblies
- Full complement of linear motion components: Rails (square and round), Motor Mounts, Bearing Mounts, Ball Nuts, Acme Plastic Nuts, Bronze Nuts, Anti-Backlash Nuts, Miniature Ball Nuts, Bearings, and more

If you don't see it, just ask us. Our application engineers will help you specify these options and modifications or they will work with you to create entirely new ones which will improve your machine's performance and lower your cost.

Design Ranges
During our 70+ years of servicing customers, our engineers have continuously developed new lead screw, ball screw, and spline assemblies required for many of industry's most unique, demanding applications. Our current product offering represents our evolving and expanding design and manufacturing capabilities.
The result of this experience is a portfolio of capabilities second to none. Thomson is the pioneer in the design and manufacture of:

- High speed ball screws – up to 300 in/min
- Telescoping assemblies – up to five sections
- Hollow shafting for low inertia and low weight
- Safety nuts with up to five redundant load paths
- Nyliner nuts, offering extreme speeds and loads
- Ultimate accuracy assemblies – up to .0002 in/ft

THOMSON
Linear Motion. Optimized.™

Date: _______ / _______ / __________

Request for Quote

Use this form if you have already selected a product. We will respond within four hours.

1. Information

Name		**Title/Dept.**	
Company Name			
Address			
Phone		**Fax**	
Email			

Note: If this product or assembly has been quoted or ordered before, please provide the quote number or order number.			
Quote No.		**Order No.**	

2. Screw and Nut Part Numbers

Qty.		**Lead Error**	0.004″/ft ☐	0.005″/ft ☐	50µ/300mm ☐	23µ/300mm ☐	12µ/300mm ☐
Diameter		**Lead**					
Screw P/N		**Overall Length***					
Ball Nut P/N		**Flange P/N**		**Wiper P/N**			

3. Bearing Supports

Right End	☐ None	☐ Floating	☐ Quick Mount
Left End	☐ None	☐ Floating	☐ Quick Mount

4. End Machining*

Right End	☐ BK	☐ BF	☐ FK	☐ FF	☐ QK	☐ QF	☐ Cut to Length Only
	☐ BK1	☐ BF1	☐ FK1	☐ FF1	☐ QK1	☐ QF1	☐ Annealed ____________ (specify length annealed)

5. Configuration*

☐ Ball Nut (V-Thread/Flange) Facing Left End	☐ Ball Nut (V-Thread/Flange) Facing Right End	☐ Modified Flange (Attach Print)

* Customer print will take precedence if provided.

Need a quote or have a question about an application?
Contact us in North America at:

Phone: 540-633-3549
Fax: 540-639-4162
Email: thomson@thomsonlinear.com

Date: _______ / _______ / _________

Application Data Sheet

Use this form if you need assistance selecting a product. We will respond within four hours.

1. Information

Name		**Title/Dept.**	
Company Name			
Address			
Phone		**Fax**	
Email			

2. Application Requirements

What is your LOAD?		☐ lbs	☐ kg
		☐ N	☐ Other (please specify)

What is your MOTION?		☐ Vertical	☐ Horizontal
		☐ Other (please specify)	

Accuracy Requirements	0.004″/ft ☐	0.005″/ft ☐	52µ/300mm ☐	23µ/300mm ☐	12µ/300mm ☐	Other (please specify)

Backlash Requirements	0.000″ ☐	0.002″ ☐	0.010″ ☐	0.05mm ☐	0.2mm ☐	Other (please specify)

Bearing Supports?	☐ Fixed/Fixed	☐ Fixed/Free	☐ Fixed/Simple
	☐ Other (please specify)		

Motor Cube Required?	☐ NEMA 17	☐ NEMA 23	☐ Other (please specify)
	☐ NEMA 42	☐ NEMA 34	

Quantity Required?		☐ per Week	☐ per Month
		☐ per Year	☐ Other (please specify)

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Lead Screws Engineering Overview

Precision Lead Screws & Supernuts®

Features/Advantages

Low Cost

Considerable savings when compared to ball screw assemblies.

Variety

Largest range of leads and diameters 3/16" to 3" to match your requirements.

Lubrication

Internally lubricated plastic nuts will operate without lubrication. However, additional lubrication or PTFE coating of the screw is recommended to optimize efficiency and life. See page 44.

Vibration and Noise

No ball recirculating vibration and often less audible noise compared to ball screws.

Custom

Option of custom designs to fit into your design envelope.

Non-Corrosive*

Stainless Steel and internally lubricated acetal.

Environment

Less susceptible to particulate contamination compared to ball screws.

Lightweight

Less mass to move.

Temperature

Ambient and friction generated heat are the primary causes of premature plastic nut failure. Observe the temperature limits below and discuss your design with our application engineers for continuous duty, high load and high speed applications. Thomson recommends bronze nuts for very high temperature environments or can aid in your selection of high temperature plastic for a custom assembly.

Efficiency

Except at very high leads, efficiency increases as lead increases. Although the internally lubricated acetal provides excellent lubricity, Ball Screw Assemblies remain significantly more efficient than any Acme design.

Design Considerations

Load

Supernuts provide a cost effective solution for moderate to light loads. For vertical applications, anti backlash supernuts should be mounted with thread/flange on the bottom.

Cantilevered Loads

Cantilevered loads that might cause a moment on the nut will cause premature failure.

Column Loading

Refer to column loading chart on page 48.

Critical Speed

Refer to critical speed chart on page 47.

Self-Locking

Lead screws can be self locking at low leads. Generally, the lead of the screw should be more than 1/3 of the diameter to satisfactorily backdrive.

Length Limitations

3/16" to 1/4"	3'
5/16" to 10 mm	4'
7/16" to 5/8"	6'
>5/8"	12'

Lead Accuracy

Standard Grade (SRA)	0.010 in/ft
Precision Grade (SPR)	0.003 in/ft

Assembly		Screws	Nuts**			
Maximum Temperature	Friction Coefficient	Material	Material	Tensile Strength	Water Absorption (24 HRS %)	Thermal Expansion Coefficient
180°F	0.08 – 0.14	Stainless Steel*	Acetal with PTFE	8,000 psi	0.15	5.4 x 10-5 in. /in. /°F

* Other materials available on a custom basis.
** Plastic nuts only. See bronze nut section for information on our bronze nut products, page 33.

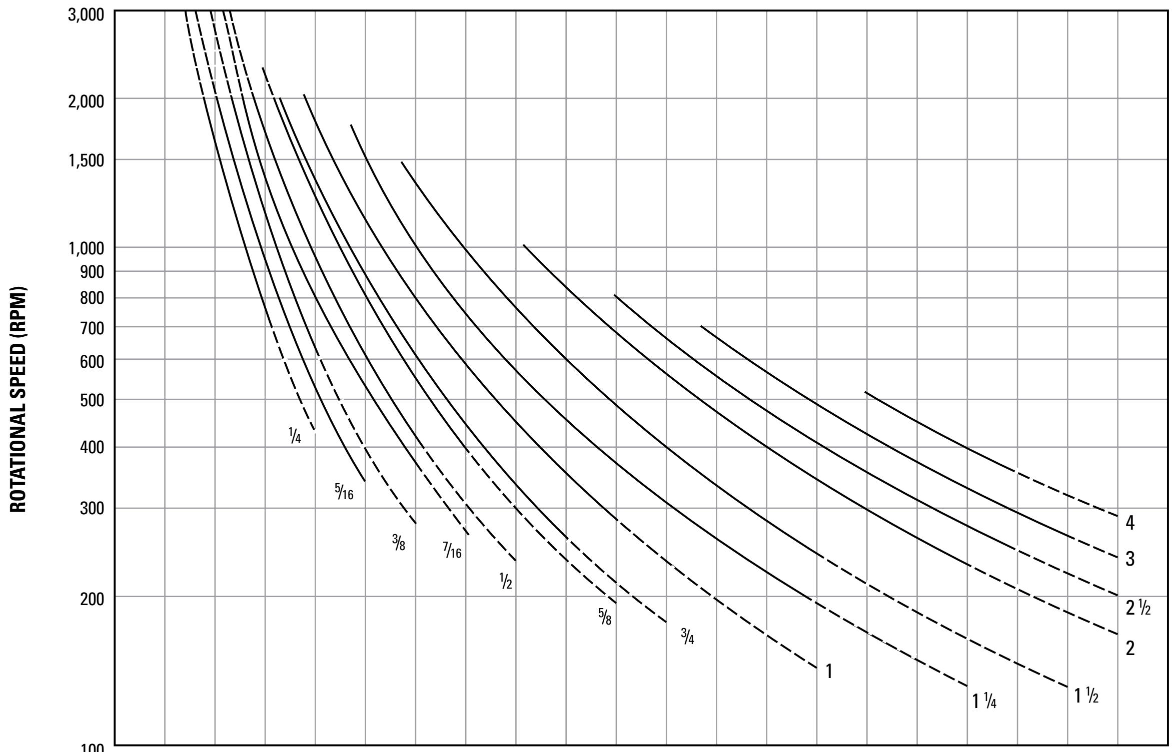
Engineering Guidelines for Lead Screws

Critical Speed Limits Chart for Lead Screws

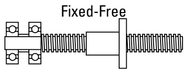
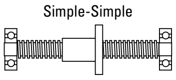
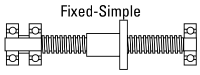
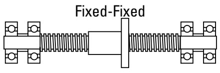
Every screw shaft has a rotational speed limit. That is the point at which the rotational speed sets up excessive vibration. This critical point is modified by the type of end bearing support used.

To use this chart, determine the required rpm and the maximum length between bearing supports. Next, select one of the four types of end supports shown below. The critical speed limit can be found by locating the point at which rpm (horizontal lines) intersects with the unsupported screw length (vertical lines) as modified by the type of supports selected below. We recommend operating at no more than 80% of the critical speed limit to allow for misalignment and/or lack of screw straightness. If speed falls into the dotted line, consult the factory.

Warning: Curves for the screw diameters shown are based on the smallest root (minor) diameter of the standard screws within the nominal size range and truncated at the maximum ball nut rotational speed. DO NOT EXCEED this rpm regardless of screw length.



MAXIMUM LENGTH (INCHES) BETWEEN BEARINGS

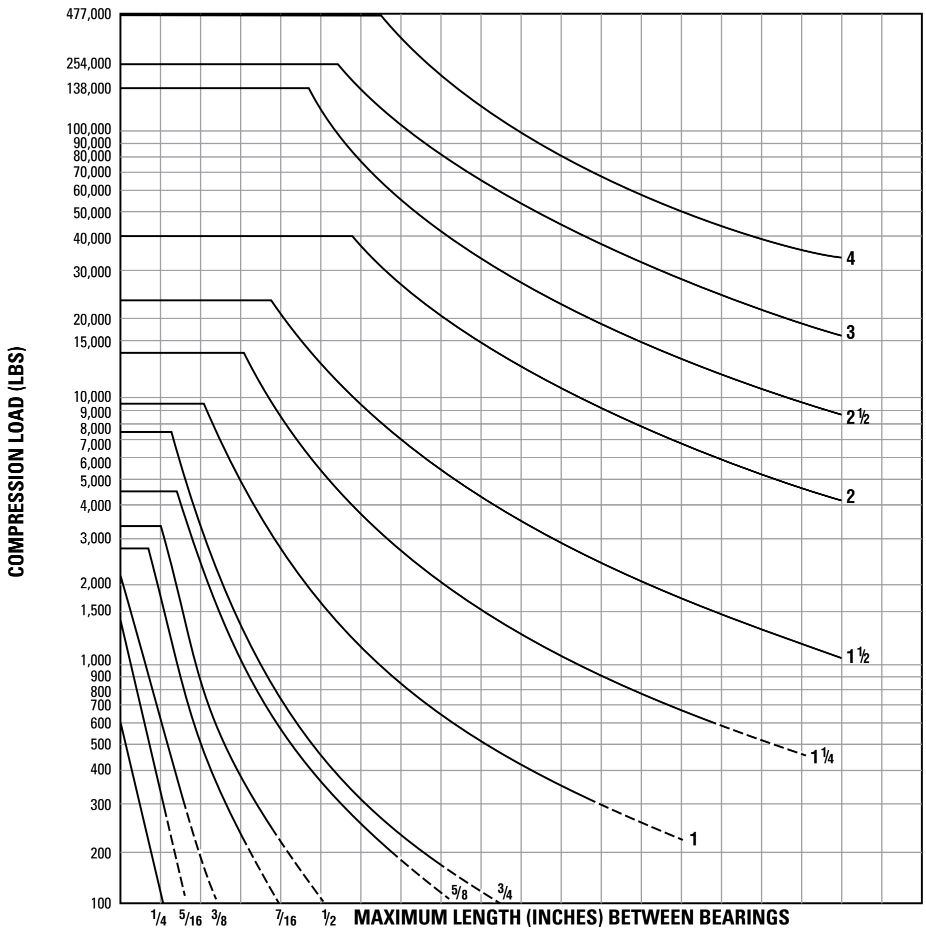
A Fixed-Free 	Inches	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	120	126
	mm	152	304	457	609	762	914	1056	1219	1371	1524	1676	1828	1981	2133	2286	2438	2590	2743	3048	3200
B Simple-Simple 	Inches	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
	mm	254	508	762	1016	1270	1524	1778	2032	2286	2540	2794	3048	3302	3556	3810	4064	4318	4572	4826	5080
C Fixed-Simple 	Inches	12	24	36	48	61	73	85	97	109	121	133	145	158	170	182	194	206	218	230	242
	mm	304	609	914	1219	1549	1854	2159	2463	2768	3073	3378	3683	4013	4318	4622	4927	5232	5537	5842	6146
D Fixed-Fixed 	Inches	15	30	45	60	75	90	105	119	134	149	164	179	194	209	224	239	254	269	284	298
	mm	381	762	1143	1524	1905	2286	2667	3022	3403	3784	4165	4546	4927	5308	5689	6070	6451	6832	7213	7569

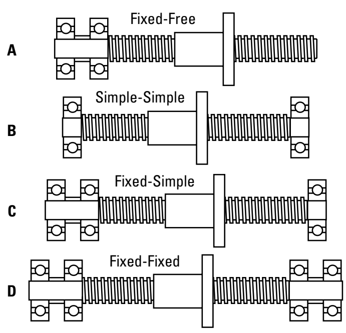
Engineering Guidelines for Lead Screws

Column Loading Capacities Chart for Lead Screws

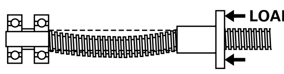
Use the chart below to determine the Maximum Compression Load for Screw Shaft. Usually, screw operated in tension can handle loads up to the rated capacity of the nut, providing the screw length is within standard lengths. End supports have an effect on the load capacity of screws. The four standard variations are shown below with corresponding rating adjustments. Find the point of intersecting lines of load (horizontal) and length (vertical) to determine the minimum safe diameter of screw. If loads fall into dotted lines, consult factory.

Warning: DO NOT EXCEED ball nut capacity. Curves for the screw diameters shown are based on the smallest root (minor) diameter of the standard screws within the nominal size range.

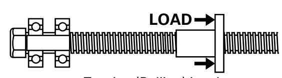




A	Inches	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
	mm	127	254	381	508	635	762	889	1016	1143	1270	1397	1524	1651	1778	1905	2032	2159	2286	2413
B	Inches	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
	mm	254	508	762	1016	1270	1524	1778	2032	2286	2540	2794	3048	3302	3556	3810	4064	4318	4572	4826
C	Inches	14	28	42	57	71	85	99	113	127	141	156	170	184	198	212	226	240	255	270
	mm	356	711	1067	1448	1803	2159	2515	2870	3226	3581	3962	4318	4674	5029	5385	5740	6096	6477	6858
D	Inches	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380
	mm	508	1016	1524	2032	2540	3048	3556	4064	4572	5080	5588	6096	6604	7112	7620	8128	8636	9144	9652



Compression (Column) Load



Tension (Pulling) Load

Formulas

Some Useful Formulas for Lead Screw Assemblies

Torque, Rotary to Linear

Rotating the screw to translate the nut, or rotating the nut to translate the screw.

Lead Screw Assemblies

$$\text{Torque (in lbs)} = \frac{\text{Load (lbs) x Lead (inches)}}{2\pi \text{ x efficiency*}}$$

* Acme screw efficiency is variable with the helix angle of the threads, the friction of the material and the finish. See the efficiency formula below.

Torque, Linear to Rotary

Translating the screw to rotate the nut, or translating the nut to rotate the screw.

Lead Screw Assemblies

$$\text{Torque (in lbs)} = \frac{\text{Load x Lead x Efficiency}}{2\pi}$$

The higher the lead of the screw, the less effort required to backdrive either the screw or the nut.
As a rule, the lead of the screw should be more than 1/3 the diameter of the screw to satisfactorily backdrive.

Efficiency

Lead Screw Assemblies

$$\text{\% Efficiency} = \frac{\tan(\text{helix angle})}{\tan(\text{helix angle} + \arctan f)} \times 100$$

f = coefficient of friction

Horsepower

Torque to Horsepower

$$hp = \frac{\text{Torque (in lbs) x rpm}}{63000}$$

Horsepower to Torque

$$\text{Torque} = \frac{63000 \text{ x hp}}{\text{rpm}}$$

Column Load Strength*

(Based on Eulers Formula)

$$P_{cr} = \frac{1.405 \times 10^7 \times F_c \times d^4}{L^2}$$

P_{cr} = maximum loads (lbs)
F_c = end support factor
- 0.25 one end fixed, other free
- 1.00 both ends supported
- 2.00 one end fixed, other supported
- 4.00 both ends fixed

d = root diameter of screw (in.)
L = distance between nut and load carrying bearing (in.)

When possible, design for tension loads to eliminate the buckling factor and reduce the required screw size

Critical Screw Shaft Speed

(Maximum rotational speed of screw)

$$C_s = F_c \times 4.76 \times 10^6 \times \frac{d}{L^2}$$

C_s = critical speed (rpm)
d = root diameter of screw (in.)
L = length between supports (in.)
F_c = end support factor
- 0.36 one end fixed, other free
- 1.00 both ends supported
- 1.47 one end fixed, other supported
- 2.23 both ends fixed

Critical shaft speed should be reduced to 80% to allow for other factors such as alignment and straightness

* Formula only valid if $L/d \geq 18.25$.

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