ACME LEAD SCREWS

CENTERLESS GROUND AND STANDARD ROLLED

2G THREADFORM

> MATERIAL:
300 Series Stainless Steel

> FEATURES:
Low cost alternative to ball screw assemblies
Ideal in corrosive environments
Well suited for vertical motion applications

> SPECIFICATIONS:
Lead accuracy: ±0.010 inches per foot
Straightness: 0.010 inches per foot

REV: 03.27.17 KT
**ANTI-BACKLASH ACME NUTS**

> **MATERIAL:**  
> Acetal with PTFE

> **TEMPERATURE RANGE:**  
> 32°F to 180°F

For use with Acme Lead Screw AB11SA-...

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### INCH COMPONENT

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<thead>
<tr>
<th>Catalog Number</th>
<th>Screw Size</th>
<th>Number of Starts</th>
<th>Lead in.</th>
<th>Efficiency %</th>
<th>O.D. Min.</th>
<th>O.D. Max.</th>
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Continued on the next page
ANTI-BACKLASH ACME NUTS

**MATERIAL:**
Acetal with PTFE

**TEMPERATURE RANGE:**
32° F to 180° F

For use with Acme Lead Screw AB11SA-...

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<th>Max. Static Load lbf</th>
<th>Drag Torque oz. in.</th>
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Continued from the previous page
MATERIAL:
Bronze SAE 660

TEMPERATURE RANGE:
-65° F to 250° F

SPECIFICATIONS:
Friction Coefficient: .2 to .3

Lubrication is recommended

For use with Acme Lead Screw AB11SA-...

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**INCH COMPONENT**

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<th>Number of Starts</th>
<th>Lead in.</th>
<th>Torque to Raise 1 lb. oz. in.</th>
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<th>Max. Static Load lbf</th>
<th>Use with Flange</th>
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**MATERIAL:**
Bronze SAE 660

**TEMPERATURE RANGE:**
-65° F to 250° F

**SPECIFICATIONS:**
Friction Coefficient: .2 to .3

Lubrication is recommended

For use with Acme Lead Screw AB11SA-...
MATERIAL:
Acetal with PTFE

TEMPERATURE RANGE:
32° F to 180° F

For use with Acme Lead Screw AB11SA-...
MATERIAL:
Acetal with PTFE

TEMPERATURE RANGE:
32° F to 180° F

For use with Acme Lead Screw AB11SA-...

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REV: 03.27.17  KT
MATERIAL:
Turcite® X (Acetal, PTFE & Silicone Filled)

TEMPERATURE RANGE:
32° F to 160° F

FEATURES:
Lightweight
Low cost
Low friction
Self-lubricating
Up to 75,000,000 inches of travel

Left-hand threads available on special order

For use with Acme Lead Screw AB11SA-...
**FLANGE MOUNT ACME NUTS**

**MATERIAL:** Acetal with PTFE

**TEMPERATURE RANGE:** 32° F to 180° F

For use with Acme Lead Screw AB11SA-...

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**INCH COMPONENT**

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MOUNTING FLANGES
FOR ACME NUTS

MATERIAL:
Aluminum 6062-T6

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FOR ACME NUTS
Ball and Acme Screw Drive Mechanisms:

This section will introduce most of the more common types of drive mechanisms found in linear motion machinery. Ideally, a drive system should not support any loads, with all the loads being handled by a bearing system. Topics discussed will include, but not be limited to, the mechanism of actuation, efficiency, accuracy, load transfer, speed, pitch, life cycle, application, and maintenance. Each type of drive system will be accompanied by a diagram and useful equations when applicable. Some of the terms used with screws, the most common drive component, are as follows:

- **lead** – advance of the nut along the length of the screw per revolution.
- **pitch** – distance between corresponding points on adjacent thread forms (pitch = lead / # of starts).
- **# of threads** – number of teeth found along a unit length of the screw (1 / pitch).
- **# of starts** – number of helical grooves cut into the length of the shaft.
- **outer diameter** – largest diameter over the threaded section (at top of threads).
- **root diameter** – smallest diameter over the threaded section (at base of threads).
- **sub** – specific type of ACME thread where the root diameter is larger to provide for a more heavy-duty screw (the threads look “stubby”).
- **critical shaft speed** – operating speed of spinning shaft that produces severe vibrations during operation. This is a function of length, diameter, and end supports.
- **maximum compressive load** – maximum load that can be axially applied to the screw before buckling or permanent deformation is experienced. Also referred to as column strength.
- **end bearing supports** – the screw must be supported at one or both ends with thrust type bearings. Depending upon the application, it may also be desirable to provide for a stiffer system by incorporating angular contact bearings (fixed support).

Although shafts, gear trains, belt and pulley, rack and pinion, and chain and sprocket drives are practical in other applications, they require special consideration when used in CNC machinery. This is because there is typically backlash associated with these types of drives, which increases the system error. Thorough technical descriptions of these types of drives can be found in the SDP/SI Components Library, www.sdp-si.com.

**Lead screws** are threaded rods that are fitted with a nut. There are many types of threads used, but the most prevalent in industry is the ACME lead screw. Because the ACME thread is an industry standardized thread style, it is easily interchanged with parts from various manufacturers. The basic function of a screw is to convert rotary input motion to linear output motion. The nut is constrained from rotating with the screw, so as the screw is rotated the nut travels back and forth along the length of the shaft. The friction on the nut is a function of environment, lubrication, load, and duty cycle; therefore, practical life cycle is difficult to quantify.

Ball screw/nut drive systems are available in a variety of sizes and tolerances. Contact is primarily sliding, resulting in relatively low efficiency and a wear rate proportional to usage. **Advantages** include the self-locking capability in back drive mode. Diameter should be at least three times greater than the lead which is good for vertical applications, low initial costs, near silent operation, manufacturing ease, and a wide choice of materials. **Disadvantages** of ACME screws include lower efficiencies (typically 30-50%, depending on nut preload) which require larger motor drives, and unpredictable service life. For increased efficiencies see Ball Screws, SDP/SI Series S6513HM...
Helpful Formulas:

When determining the amount of input torque required to produce an amount of output linear force, there are many factors to consider. The following equations provide a practical approach in making force and torque calculations.

**Force Calculations:**

\[ F_T = F_A + F_E + F_F \]  
(1)

where:
- \( F_T \) = Total Force
- \( F_A \) = Acceleration Force
- \( F_E \) = External Force
- \( F_F \) = Friction Force

\[ F_A = \frac{W}{g} \times \frac{a}{12} \text{ lb.} \]  
(2)

where:
- \( W \) = total weight to accelerate (lb.)
- \( a \) = linear acceleration (in./sec\(^2\))
- \( g \) = acceleration from gravity (ft./sec\(^2\))

External Force \( F_E \) may be due to gravity in vertical applications, or may be from external work requirements (feeding material, stretching material, etc.).

Friction Force \( F_F \) required to overcome all of the friction in the load bearing system (with a low friction bearing system, this can be negligible).

The Total Force must be below the compressive (thrust) rating of the screw chosen. A modest factor of safety should be added to the total force so that unexpected dynamic loads are safely handled by the screw system.

**Torque Calculations:**

\[ T = F_T \times \frac{L}{2\pi e} \]  
(3)

where:
- \( F_T \) = Total Force (lbs)
- \( L \) = Lead (inches)
- \( e \) = efficiency (no units, use 0.9 for Ball screw assemblies.)

Total Force = 100 lbs  
Lead = 0.20 inches  
Efficiency = 0.9 (Ball screw)

\[ T = \frac{100 \text{ lbs} \times 0.20 \text{ inches}}{2\pi(0.9)} = 3.54 \text{ lb.-inches} \]  

Total Force = 25 lbs  
Lead = 0.10 inches  
Efficiency = 49%

\[ T = \frac{25 \text{ lbs} \times 0.10 \text{ inches}}{2\pi(0.49)} = 0.81 \text{ lb.-inches} \]  

The Torque required should be well below the torque rating of the motor chosen. A modest factor of safety should be added to the torque required so that unexpected dynamic loads are safely handled by the driving system.
Selecting and Sizing Screw Drive Systems:

When choosing a particular screw for a given application, there are several factors to be considered. Required rpm, critical speed and maximum compressive strength are the most important design features that determine screw design parameters, and can be calculated according to the following equations. Since thread style design is irrelevant in these calculations, the same equations and charts can be used for both lead screws and ball screws. Bearing configuration must be considered when using these equations. The following diagrams represent the typical bearing end support arrangements.

\[
\text{rpm} = \frac{\text{linear velocity (in./min.)}}{\text{lead (in./rev.)}}
\]

Maximum Speed:

\[
C_s = F(4.76 \times 10^6) \frac{d}{L^2}
\]

where:
- \(C_s\) = critical speed (rpm)
- \(d\) = root diameter of screw (inches)
- \(L\) = length between supports (inches)
- \(F\) = end support factor (see diagram)
  - case A: 0.36
  - case B: 1.00
  - case C: 1.47
  - case D: 2.23

Maximum Load:

\[
P = F(14.03 \times 10^6) \frac{d^4}{L^2}
\]

where:
- \(P\) = maximum load (lbs) (critical load)
- \(d\) = root diameter of screw (inches)
- \(L\) = maximum distance between nut and load carrying bearing
- \(F\) = end support factor (see diagram)
  - case A: 0.25
  - case B: 1.00
  - case C: 2.00
  - case D: 4.00

The formulas above can be represented graphically by the charts on following pages. These charts have been compiled for screws made of stainless steel. Speeds, loads, diameters, bearing arrangements, and products are referenced. It must be realized that a screw may be able to rotate at very high rpm’s, but the nut may have more strict limitations. For this reason, we have truncated the ball screw rpm diagrams to a top end of 4000 rpm and provided each type screw with their own charts. Please note that the ball screw charts are only represented for screws of 16 mm and 25 mm diameters.
Travel Rate vs. Length
For Standard ACME Lead Screws

Travel Rate in inches/min.

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<th>Ref B</th>
<th>Ref C</th>
<th>Ref D</th>
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One End Fixed
Other End Free

Both Ends Supported

One End Fixed
Other End Supported

Both Ends Fixed
PURPOSE
This graph was designed to simplify the selection of the proper lead screw so as to avoid lengths and speeds which will result in vibration of the assembly (critical speed). The factors which can be controlled after a particular maximum length is determined are: method of bearing support and choice of lead screw diameter.

USE OF THE GRAPH
1. Choose preferred bearing support means, based on design considerations.
2. On the proper bearing support horizontal line (A, B, C or D) choose length of lead screw.
3. Draw vertical line at the lead screw length, determined at (2.), and draw a horizontal line at the travel rate.
4. All screw diameters to the right and above the intersection point in (3.) are suitable for this application.
5. Screw sizes are coded as follows:

   ![Diagram of screw sizes]

   - Diameter (in).
   - Starts
   - Threads / in.

Maximum Length (in.) Adjusted for Bearing Support
   "Y" Dimension

   ![Diagram of maximum lengths adjusted for bearing support]
PURPOSE
This graph was designed to simplify the selection of the proper lead screw so as to avoid buckling when subjected to the axial loading by means of the nut. The factors which can be controlled after a particular maximum length is determined are: method of bearing support and choice of lead screw diameter.

USE OF THE GRAPH
1. Choose preferred bearing support means, based on design considerations.
2. On the proper bearing support horizontal line (A, B, C or D) choose length of lead screw.
3. Draw vertical line at the lead screw length, determined at (2.), and draw a horizontal line at the compression load the unit is exerting on the screw.
4. All screw diameters to the right and above the intersection point in (3.) are suitable for this application.
5. Screw sizes are coded as follows:

![Diagram of lead screw dimensions]

Maximum Length (in.) Adjusted for Bearing Support “X” Dimension

A

B

C

D
CRITICAL SPEED & LOAD
LOAD AND SPEED LIMITS ON 16 mm BALL SCREWS

CRITICAL SPEED

Speed rpm

Length mm

FO – Fixed, Open

FS – Fixed, Simple

SS – Simple, Simple

BEARING SUPPORT TYPES

FF – Fixed, Fixed

FO – Fixed, Open

FS – Fixed, Simple

SS – Simple, Simple

CRITICAL LOAD

Load kg

Length mm

FO – Fixed, Open

FS – Fixed, Simple

SS – Simple, Simple
CRITICAL SPEED & LOAD
LOAD AND SPEED LIMITS ON 25 mm BALL SCREWS

CRITICAL SPEED

Speed rpm

CRITICAL LOAD

Load kg

BEARING SUPPORT TYPES

FF – Fixed, Fixed
FO – Fixed, Open
FS – Fixed, Simple
SS – Simple, Simple
BALL & ACME LEAD SCREW TECHNICAL INFORMATION

BALL & ACME LEAD SCREW ASSEMBLY
LIFE EXPECTANCY

**SPECIFICATIONS**

<table>
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\[ L = \left( \frac{C_a}{F_m} \right)^3 \times 10^5 \]

- \( L \) = life expectancy expressed in number of revolutions
- \( C_a \) = dynamic load rating (N) [for acme nuts, see design load column on catalog pages]
- \( F_m \) = average axial load (N)

Example: For 10 mm pitch screw, 16 mm dia., \( C_a = 4200 \) N carrying an average axial load, \( F_m = 200 \) N (45 lbs) the expected life is:

\[ L = \frac{4200^3 \times 10^5}{200} = 9.261 \times 10^9 \text{ revolutions.} \]

At an average of 1000 rpm this will result in:

\[ \frac{9.261 \times 10^9 \text{ revolutions}}{1000 \text{ rpm}} \times \frac{1 \text{ hour}}{60 \text{ minutes}} = 154,000 \text{ hours} \]

of expected operational life. Note that the nature of the motion (jerky, smooth, etc.) will affect the life expectancy.
Lead Screw Formulas and Sample Calculations:

**Linear Speed (ipm)**

\[
\text{Linear Speed} = \frac{\text{steps / second}}{\text{steps / revolution}} \times 60 \times \frac{1}{p}
\]

where:
- \( p \) = lead screw pitch in threads per inch

**Axial Force (lb)**

\[
\text{Force} = \frac{2\pi}{16} \times T \times p \times \text{eff.}
\]

where:
- \( T \) = torque (oz.\( \cdot \)in.)
- \( p \) = lead screw pitch in threads per inch
- \( \text{eff.} \) = efficiency expressed as a decimal: 90% = 0.90

**Note:** Ball screws are generally 85% to 95% efficient. Acme lead screw efficiency is generally 35% to 45%, but can be as high as 85%.

**A.** Calculating the torque required to accelerate a mass moving horizontally and driven by a ball bearing lead screw and nut. The total torque the motor must provide includes the torque required to:

a. accelerate the weight
b. accelerate the lead screw
c. accelerate the motor rotor
d. overcome the frictional force

To calculate the rotational equivalent of weight \( w \):

\[
I_{(eq)} = w \times \frac{1}{p^2} \times \left( \frac{1}{2\pi} \right)^2
\]

where:
- \( w \) = weight (lb.)
- \( p \) = pitch (threads per inch)
- \( I_{(eq)} \) = equivalent polar inertia (lb.\( \cdot \)in.\(^2\))

to calculate lead screw inertia (steel screw)

\[
I_{(screw)} = D^4 \times \text{length} \times 0.028
\]

**Example:**

Weight = 1000 lb.
Velocity = 0.15 feet per second
Time to Reach Velocity = 0.1 seconds
Ball Screw Diameter = 1.5 inches
Ball Screw Length = 48 inches
Ball Screw Pitch = 5 threads per inch
Motor Rotor Inertia = 2.5 lb.\( \cdot \)in.\(^2\)
Friction Force to Slide Weight = 6 oz.

\[
I_{(eq)} = w \times \frac{1}{p^2} \times 0.25 = 1000 \times \frac{1}{25} \times 0.25 = 1.0 \text{ lb.}\( \cdot \)in.\(^2\)
\]

\[
I_{(screw)} = D^4 \times \text{length} \times 0.028 = 5.06 \times 48 \times 0.028 = 6.8 \text{ lb.}\( \cdot \)in.\(^2\)
\]

\[
I_{(rotor)} = 2.5 \text{ lb.}\( \cdot \)in.\(^2\)
\]

\[
I_{(total)} = 10.3 \text{ lb.}\( \cdot \)in.\(^2\)
\]

Velocity is 0.15 feet per second, which is equal to 1800 steps per second (motor steps in 1.8° increments).
Torque to accelerate system:

\[ T = 2 \times \frac{I}{t} \times \omega \times \frac{\pi \times 1.8}{180} \times \frac{1}{24} = 2 \times 10.3 \times \frac{1800}{0.1} \times \frac{3.1416 \times 1.8}{180} \times \frac{1}{24} = 484 \text{ oz.}\cdot\text{in.} \]

Torque to overcome friction:

\[ F = 0.22 \times 6 = 1.32 \text{ oz.}\cdot\text{in.} \]

where:

\[ F = \text{frictional force (lb.)} \]
\[ T = \text{torque (oz.}\cdot\text{in.)} \]
\[ \rho = \text{lead screw pitch (threads per inch)} \]

Total torque required = 484 oz.\cdot in. + 1.32 oz.\cdot in. = 485.32 oz.\cdot in.

After determining the required motor size, it is recommended to add a 20% factor of safety so that unexpected dynamic loads are easily handled by the motor.

Sizing Servo Motors:

Two separate torque figures are needed when selecting a DC motor — a peak torque, being the sum of acceleration and friction torques, and a continuous torque, which is the friction component only. The torque produced by the motor is given by:

\[ T = K_T I \]

where \( K_T \) is the motor torque constant (e.g., Nm/amp) and \( I \) is the drive current (amp). The choice of motor and drive must satisfy the following conditions:

1. The product of \( K_T \) and peak drive current must give the required peak torque.
2. The product of \( K_T \) and continuous drive current must produce sufficient continuous torque.
3. The maximum allowable motor current must be greater than the peak drive current.
4. At maximum speed and peak current, the voltage developed across the motor must be less than 80% of the drive supply voltage.

The voltage across the motor is given by:

\[ E = K_e \omega + R I \]

where \( K_e \) is the motor voltage constant, \( \omega \) the speed, \( R \) the winding resistance (ohms) and \( I \) the peak current (amperes).

The speed units should be the same in each case; i.e., if the voltage constant is in volts per radian per second, then \( \omega \) should also be in radians per second.

To make the most efficient use of the drive, the chosen solution should utilize most of the peak drive current and most of the available voltage. Motor manufacturers usually offer alternative windings, and care should be taken to select the most appropriate.

Example:

Leadscrew Length: 80 in.
Leadscrew Diameter: 1.5 in.
Leadscrew Pitch: 2.54 in.
Table Weight: 1000 lb.
Linear Table Speed Required: 472 inches/min.
Acceleration Time: 120 ms

Inertia of Leadscrew: \( J = \frac{D^4 L}{36} = 11.25 \text{ lb.}\cdot\text{in.}^2 \)

Inertia of Table: \( J = \frac{W}{40 \rho^2} = 3.88 \text{ lb.}\cdot\text{in.}^2 \)

Total inertia = 15.13 lb.\cdot\text{in.}^2

Maximum Speed = 472’/min. = 1200 rpm (equivalent to 4000 full steps/sec)
Acceleration Torque:

\[ T = \frac{J \omega^2}{764^2} = 660 \text{ oz}\cdot\text{in.} \times (4.65 \text{ N}\cdot\text{m}) \]

This takes no account of motor inertia, so a suitable motor will be capable of producing around 1000 oz\cdot\text{in.} torque.

Again, as with stepper selection, it is recommended to add a 20% factor of safety so that unexpected dynamic loads are easily handled by the motor.

**Bending Formulas for Extruded Profiles:**

The deflection of a beam depends on how it is supported, the magnitude of the load it carries, the distribution of the load and the distance from the supports. Two examples will be considered — the simple beam and the cantilevered beam.

The deflection of a simple beam with the load concentrated at the center is given by the following equation:

\[ y = \frac{P l^3}{48 EI} \]

The deflection of a cantilevered beam with the load concentrated at the free end is given by the following equation:

\[ y = \frac{P l^3}{3 EI} \]

where:
- \( y \) = beam deflection at the loading point, cm
- \( P \) = concentrated loads, kgf
- \( l \) = length of beam, cm
- \( x \) = distance from support to any section, cm
- \( E \) = modulus of elasticity, kg/cm²
- \( I \) = moment of inertia, cm⁴

**Example 1:**

Structural Profile 40 x 80 is used as a simple beam with 100 cm between supports. If this beam carries a 100 kg load concentrated at the center of the beam, how much will the beam bend?

The modulus of elasticity of the aluminum alloy used for all the extrusions listed as example is 702,949 kg/cm. The moment of inertia for this beam is given which describes this beam. Since this beam is not symmetrical, two moments of inertia are given. Select the value corresponding to the way in which the beam will be used. For this example, we assume that the load is applied along the y-axis. The moment of inertia is 21.17 cm⁴.

Substituting these values and the values from the example into the equation for the deflection of a simple beam, we obtain:

\[ y = \frac{100 \text{ kg} \times (100 \text{ cm})^3}{48 \times (702949 \text{ kg/cm}^2) \times (21.17 \text{ cm}^4)} = 0.14 \text{ cm} \]

**Example 2:**

Structural Profile 40 x 80 is supported at one end and a concentrated load is applied to the free end, 100 cm from the fixed end. Calculate the bending at the free end.

Substituting these values and the value for the modulus of elasticity and moment of inertia above, we obtain:

\[ y = \frac{100 \text{ kg} \times (100 \text{ cm})^3}{3 \times (702949 \text{ kg/cm}^2) \times (21.17 \text{ cm}^4)} = 2.24 \text{ cm} \]
**Ball and Acme Screw Application Worksheet**

<table>
<thead>
<tr>
<th>Name:</th>
<th>Phone:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company Name:</td>
<td>Fax:</td>
</tr>
<tr>
<td>Address 1:</td>
<td>Address 2:</td>
</tr>
<tr>
<td>City:</td>
<td>State:</td>
</tr>
<tr>
<td>Zip code:</td>
<td>Brief Description of Application:</td>
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<tr>
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<td></td>
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<tr>
<td>Max. Load:</td>
<td></td>
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<tr>
<td>Max Speed:</td>
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<tr>
<td>Max. Accel:</td>
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<tr>
<td>Travel:</td>
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<tr>
<td>Complete Cycle Time:</td>
<td></td>
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<tr>
<td>Orientation:</td>
<td></td>
</tr>
<tr>
<td>Accuracy Needed: (please circle)</td>
<td></td>
</tr>
<tr>
<td>Anti-Backlash Nut Required: <strong>YES</strong> or <strong>NO</strong></td>
<td></td>
</tr>
<tr>
<td>Integral Flange Nut Required: <strong>YES</strong> or <strong>NO</strong></td>
<td></td>
</tr>
<tr>
<td>Finished End Required: <strong>YES</strong> or <strong>NO</strong></td>
<td></td>
</tr>
<tr>
<td>End Bearing Required: <strong>YES</strong> or <strong>NO</strong></td>
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</tr>
<tr>
<td>Base Mount of Flange Mount of End Bearings:</td>
<td></td>
</tr>
<tr>
<td>Supply drawing (Note: Finished ends for OEM quantities only i.e. 25 or higher)</td>
<td></td>
</tr>
</tbody>
</table>

*Please use this for any notes or diagrams*