Nook Planetary Roller Screws (NRS), a member of the lead screw family, are remarkable devices designed to convert rotary motion in axial force or vice versa.

The NRS design offers multiple advantages and reliability for the most demanding applications when compared with other lead screw types due to its rolling motion. NRS offer high efficiency even in relatively shallow lead designs. The multitude of contact points can carry large loads and provide very high resolution (small axial movement) when using very shallow leads. NRS produce high rotational speeds with faster acceleration without adverse effects.

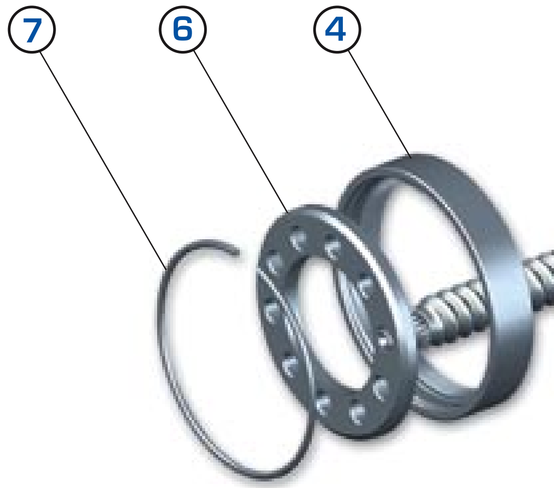
NRS planetary roller screws shown in the following pages cover a large spectrum of possibilities and application requirements. Nook engineers are at your disposal to suggest the suitable product for your application requirements.

NRS PLANETARY ROLLER SCREWS ARE USED IN:

AEROSPACE & OUTER SPACE APPLICATIONS
MACHINE TOOLS • MEASURING EQUIPMENT
POSITIONING SYSTEMS • OPTICAL EQUIPMENT
PHOTOGRAPHY EQUIPMENT • ORDNANCE
HIGH FORCE ACTUATORS • PLASTIC MACHINERY
TRANSPORTATION (TRAIN TILT MECHANISMS)

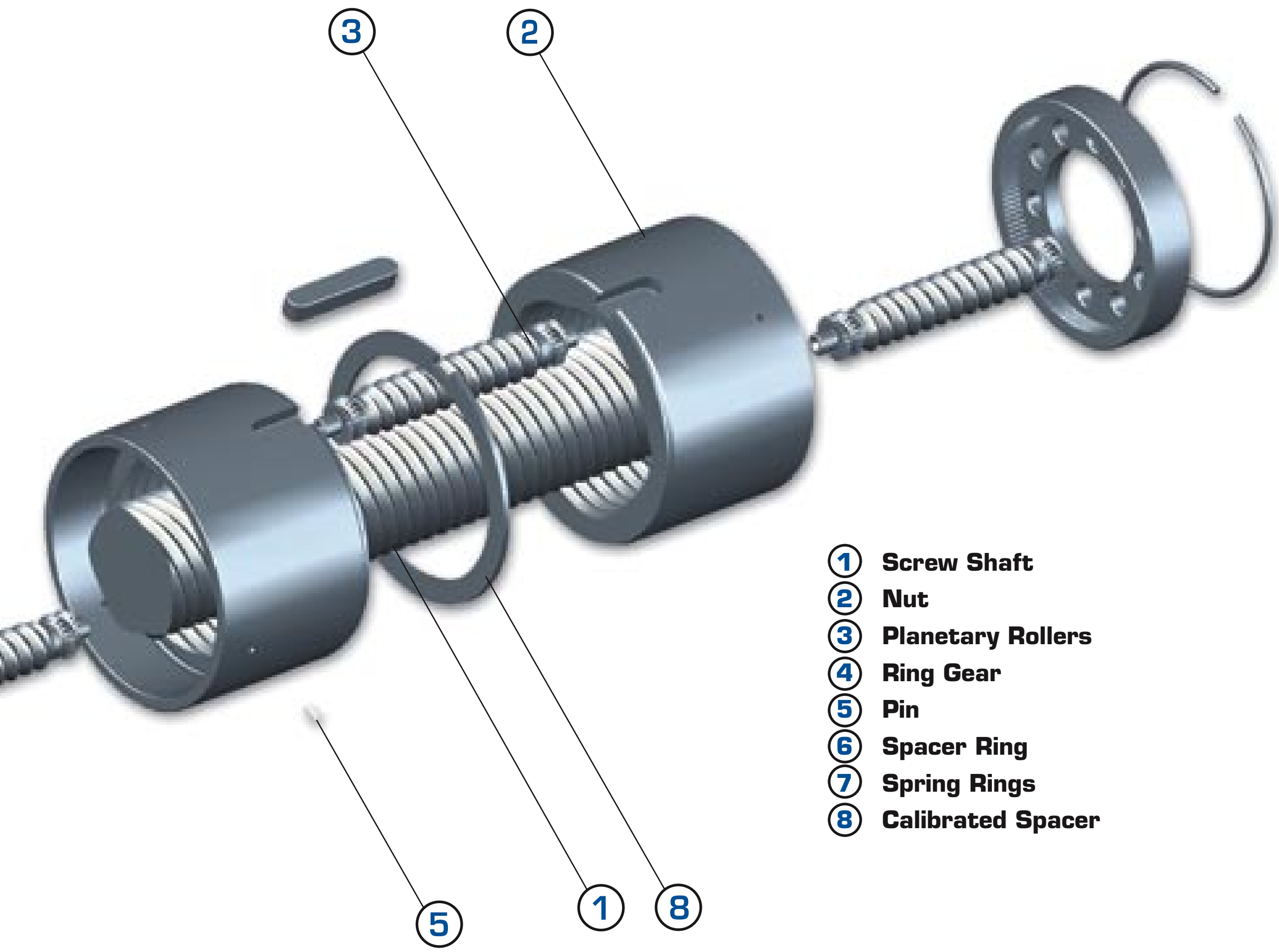
NRS DESIGN ELEMENTS

NRS planetary roller screws utilize threaded rollers instead of bearing balls as rolling elements. The apparent lead angle of the nut and rollers are identical to prevent axial migration of the rollers. In the exploded screw illustration the basic planetary roller screw is composed of a screw shaft (**1**), nut (**2**) and several planetary rollers (**3**).



Both screw shaft and nut have a thread profile with straight flanks and both have multi-start threads. The rollers have a single-thread start with the thread profile modified so that the contact is similar to a ball/plane.

The rollers have a gear and a cylindrical journal at each end. The gear at the roller ends meshes with the ring gear (**4**) at each end of the nut. This mesh prevents unwanted roller skewing by maintaining parallel axes of the planetary roller and the screw shaft. Ring gears are timed at assembly and fixed to the nut by pins (**5**). Roller cylindrical journals are inserted into the spacer ring (**6**). The spacer ring is free to rotate and it is retained in the nut by spring rings (**7**). The roller nut can be one-piece (not shown) or split style (as shown). The split nut can be used to reduce the axial lash or to provide a preloaded system. To achieve preload, a calibrated spacer (**8**) is placed between the two nut halves.



1. Screw Shaft
2. Nut
3. Planetary Rollers
4. Ring Gear
5. Pin
6. Spacer Ring
7. Spring Rings
8. Calibrated Spacer

PRELOADED NRS

Split nuts are installed with two halves pushed against each other and the clearance removed for preload. Due to the large number of contacts and great rigidity, a planetary roller screw does not require high preload amounts to perform backlash-free in most application conditions. Split nuts only carry load on a reduced length of thread (half length minus the half-thickness of the calibrated spacer).

NON-PRELOADED NRS

One-piece solid nuts do not have a have a calibrated spacer to remove backlash. One-piece nuts have larger load ratings since all threads of the nut can carry load.

NRS MATERIALS

NRS planetary roller screws are made of high strength materials. The screw shaft is made of medium carbon induction hardenable alloy steel. The rollers and nut are manufactured from high grade bearing steel. All rolling surfaces are heat treated to a surface hardness not less than 56 HRC with a case depth suitably chosen to carry the load. Other materials, such as stainless steel, can be provided upon request.

CRITERIA FOR SELECTION OF ROLLER SCREWS

HIGH STATIC LOAD:
Static load ratings as high as 9,500 kN are available

SMALL LEAD APPLICATIONS:
Leads of 1mm are available with a screw diameter of 50mm

HIGH LINEAR SPEEDS:
Linear velocities of 120 m/min or higher are possible with high lead screws

HIGH LINEAR AND ANGULAR ACCELERATION:
Test have been successfully conducted with angular accelerations of 7,000 radians/s^2

SHOCK LOADS OR ADVERSE ENVIRONMENTAL CONDITIONS:
Roller screws kept operating in tests with poor lubricating conditions and after ingesting ice and sand

CALCULATION AND SELECTION

Basic dynamic load ratings C and L_{10} life

Dynamic load rating is used to calculate the fatigue life of a NRS planetary roller screw. The dynamic load rating is defined as a load, constant in magnitude and direction under which 90% of a statistically significant number of apparently identical planetary roller screws reach an operating life of 10^6 revolutions (L_{10}).

Static load ratings (C_0) and safety factors (S_0)

Static load rating C_0 is a load that would cause a permanent deformation at the most heavily loaded contact equal to 0.0001 of the curvature diameter of the rolling element. In order to prevent deformations that could impair the proper function and the operating noise of the planetary roller screw a safety factor S_0 should be used when selecting a roller screw on the basis of its static load rating.

The S_0 factor should not be less than 3. For operations with quasi-static load applications (i.e. presses) where the load occurs primarily on the same portion of the stroke, it is recommended to use higher S_0. If size constraints prevent the use of larger screws and the operation of the device is such that the S_0 approaches 1, please inquire with our engineering department.

Theoretical life

Theoretical life L_{10} or L_h is the operating time reached by 90% of a group of apparently identical planetary roller screws operating under the same conditions. The theoretical life is calculated as follows:

$$L_{10} = \left(\frac{C}{P}\right)^3$$

If operation reliability higher than 90% is required, than the theoretical life must be corrected by using a reliability factor (a_n) according to the table.

$$L_n = L_{10} \times a_n$$

Reliability (%)	Factor a_n
90	1
95	0.62
96	0.53
97	0.44
98	0.33
99	0.21

Theoretical life, normally expressed in 10^6 revolutions, can be expressed in different operating units, such as hours, as follows

$$L_h = \frac{10^6}{(n_{eq} \times 60) \times \left(\frac{C}{P}\right)^3}$$

Where:

n_{eq} = screw equivalent rotational speed

Equivalent load

Operating loads can be defined by physical characteristics (i.e. masses, inertia, etc.) that operate on the screw. For systems with varying conditions, such as changes of load magnitude and duration as well as speed, the simple calculation cannot be employed and an equivalent load should be assessed.

The equivalent load is a calculated mean operating load used for determining life and is dependent upon load pattern.

The equivalent load can be computed using the following formula:

$$P = \sqrt[3]{\frac{q_1 x n_1 x F_{ax1}{}^3 + q_2 x n_2 x F_{ax2}{}^3 + \ldots + q_n x n_n x F_{axn}{}^3}{q_1 x n_1 + q_2 x n_2 + \ldots + q_n x n_n}}$$

The equivalent speed can be computed as follows:

$$n_{eq} = \frac{(q_1 x n_1 + q_2 x n_2 + \ldots + q_n x n_n)}{100}$$

Where:

$F_{ax(1,2,n)}$ = Applied load in the individual time step

$n_{(1,2,n)}$ = screw rotational speed in the individual load steps

$q_{(1,2,n)}$ = time step in %

Preload

Preloaded nuts are used to eliminate axial lash and to increase system rigidity. Preload is detrimental to the operating life and should be selected carefully. The preload magnitude should be accounted for in the equivalent load calculation so its impact on the system life can be determined.

Preload magnitude should be selected as a function of the operating conditions. In case the varying steps cannot be easily identified, the preload magnitude can be assessed as follows:

$$F_p = \frac{F_{max}}{2.83}$$

The resulting load (inclusive of preload and operating load) can be calculated as follows:

Loaded nut (or half-nut):

$$P = F_p + 0.65 \text{ x } F_{ax} \; (\text{for } F_{ax} < 2.83 \text{ x } F_p)$$
$$P = F_{ax} \; (\text{for } F_{ax} \geq 2.83 \text{ x } F_p)$$

Relieved nut (or half nut):

$$P = F_p - 0.35 \text{ x } F_{ax} \; (\text{for } F_{ax} < 2.83 \text{ x } F_p)$$
$$P = 0 \; (\text{for } F_{ax} \geq 2.83 \text{ x } F_p)$$

Where:

P = resulting equivalent load
F_p = preload magnitude
F_{ax} = applied load

Rigidity of a roller screw

The rigidity of a roller screw assembly is a function of several parameters, such as: nut rigidity, bearing support rigidity, screw shaft rigidity, mounting housing rigidity as well as the mounting arrangement. If known, all of the parameters can be assembled in a formula as follows:

$$C_{\delta t} = \left(\frac{1}{C_{\delta s}} + \frac{1}{C_{\delta n}} + \frac{1}{C_{\delta b}} + \frac{1}{C_{\delta h}} \right)^{-1}$$

Where:

$C_{\delta t}$ = total system rigidity
$C_{\delta s}$ = screw shaft rigidity
$C_{\delta n}$ = screw nut rigidity
$C_{\delta b}$ = support bearing rigidity
$C_{\delta h}$ = housing rigidity

The screw rigidity can be calculated as follows:

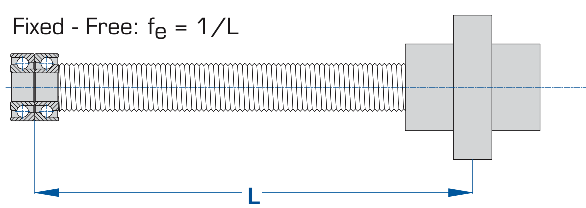
$$C_{\delta s} = 165 \text{ x } d_o{}^2 \text{ x } f_e$$

Where:

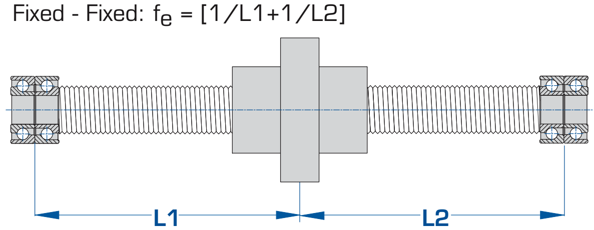
f_e = factor dependent on end-support configuration
(see illustration below)

RIGIDITY f_e factor

Fixed - Free: $f_e = 1/L$



Fixed - Fixed: $f_e = [1/L1 + 1/L2]$



The nut rigidity can be calculated as follows:

$$C_{\delta n} = \sqrt[3]{f_n \times F_{ax}}$$

The factor f_n can be supplied upon request.
The customer must determine the rigidity of the bearings and housing.

Column strength

If the screw is subjected to compressive loads, then a verification of its suitability to the loading conditions can be performed as follows:

$$F_{ax\ allowed} = \frac{f_{sc} \times d_o^4 \times 10^4}{L^2}$$

Where:

f_{sc} = factor dependent on end-support configuration (see table below)

d_o = screw nominal diameter

L = free-length

Critical speed

The maximum achievable rotational velocity of planetary roller screws is affected by the following parameters:

- Rotational speed capability of the nut (and planetary train)
- Diameter and free length of the screw (for rotating screw shafts)
- End support configuration (for rotating screws)
- Rotation member (nut or screw)

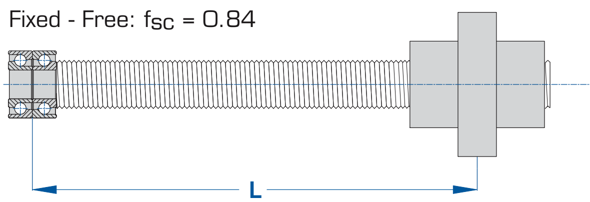
While the rotational capability of the nut can be easily assessed since it depends upon the maximum rotational factor DMn (mean diameter of the planetary train x rotational velocity n), the critical speed of the screw shaft must be calculated for each application. This value is normally considered the threshold at which the screw will start to resonate (1st order). The nut DMn factor equals 140,000.

The critical speed is calculated as follows:

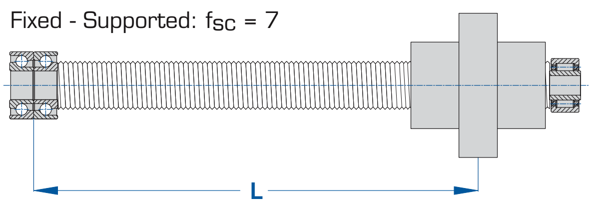
$$n_{max} = \frac{f_{sn} \times d_o \times 10^7}{L^2}$$

COLUMN STRENGTH f_{sc} factor

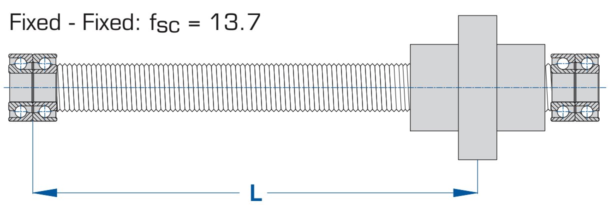
Fixed - Free: f_{sc} = 0.84



Fixed - Supported: f_{sc} = 7

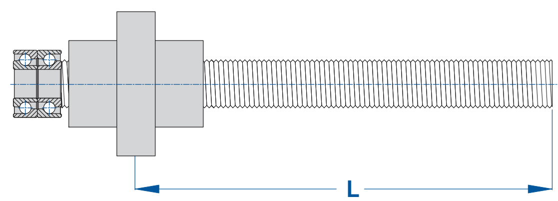


Fixed - Fixed: f_{sc} = 13.7

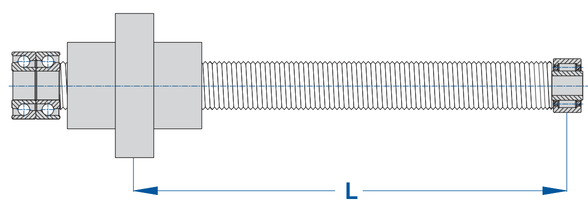


CRITICAL SPEED f_{sn} factor

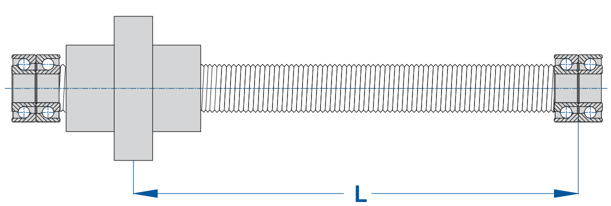
Fixed - Free: f_{sn} = 3.5



Fixed - Supported: f_{sn} = 15.3



Fixed - Fixed: f_{sn} = 22.3



Where:

n_{max} = allowable screw rotational velocity
f_{sn} = factor dependent upon the end-support configuration (see table on previous page)
d_o = screw nominal diameter
L = screw free-length

Efficiency and driving torque

Efficiency of the NRS planetary roller screw is dependent upon its operating parameters. The friction of the system is dependent upon varying factors that cannot be easily summarized here. To simplify the selection of the screw size, the following formulae can be used.

$$\eta_1 = \frac{1}{1 + \left(\frac{f_f \times d_o}{p_{ho}}\right)}$$

for transforming rotary motion in axial motion

$$\eta_2 = 1 - \left(\frac{f_f \times d_o}{p_{ho}}\right)$$

for transforming axial motion into rotary motion

Where:

f_f = friction factor (mean value = 0.038)
p_{ho} = screw lead

Torque required

To move an axial load at constant speed, the screw will require a motor torque and its magnitude can be calculated as follows:

$$M_t = \frac{F_{ax} \times p_{ho} \times 10^3}{2 \times \pi \times \eta_1}$$

By contrast, to restrain an axial load, the screw must be equipped with a brake and the restraining torque is calculated as follows:

$$M_b = \frac{F_{ax} \times p_{ho} \times \eta_2 \times 10^3}{2 \times \pi}$$

Note: The start-up torque required will be greater than the calculated value M_t above.

LUBRICATION & MAINTENANCE

NRS planetary roller screws, like all rolling element systems, must be lubricated in order to operate properly.

The screws can be lubricated with oil or grease. The application demands will dictate which media is more suited for the task.

Grease lubrication

Nook PAG-1 is available in a 1 lb. can for applications that require grease lubrication. High quality greases should be used whenever possible. The grease used must not contain solid additives in any form. Greases suitable for lubricating screws must contain EP additives as well as anti-wear additives.

The lubricant characteristics, the amount to be used and its replenishment interval are a function of the application. Factors such as load, stroke length, operating temperature, environment cleanliness, operating speed will impact the lubricant suitability and durability.

Nook engineers will gladly provide guidance on the selection of suitable grease as well as the maintenance interval.

Oil lubrication

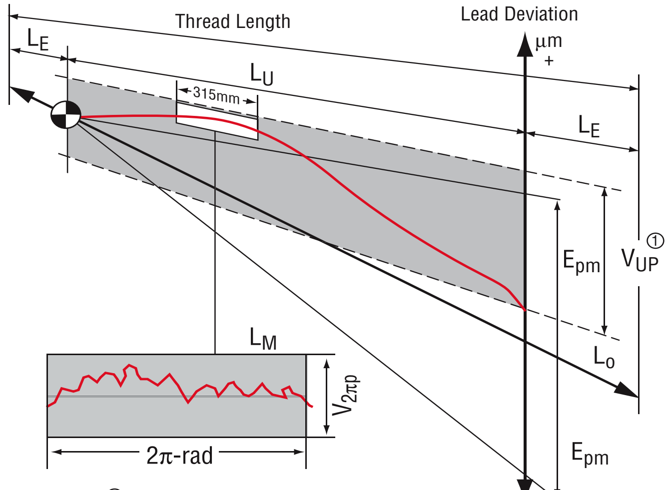
Nook E-900L is available in a 32 oz. bottle for applications that require oil lubrication. Applications that operate with high loads and continuous motion may operate only with oil lubrication. The basic oil viscosity, the presence of additives and the lubricant flow should be assessed during the design phase.

Nook engineers will gladly provide guidance on the selection of a suitable oil, as well as the proper flow, to insure the system operates as intended.

ACCURACY

NRS planetary roller screws are produced in quality classes according to ISO 1, 3 and 5 standards. The summary of the characteristics and their allowable error are reported below.

Accuracy class	Tolerance * (μm)
G1	±6
G3	±12
G5	±23



① Band width for whole measurement Distance

EFFECTIVE THREAD LENGTH L_u		ACCURACY CLASS					
		G1 ($V_{2\pi p}$ = 2μm)		G3 ($V_{2\pi p}$ = 2μm)		G5 ($V_{2\pi p}$ = 2μm)	
from (mm)	to (mm)	e_{pm} (μm)	V_{up} (μm)	e_{pm} (μm)	V_{up} (μm)	e_{pm} (μm)	V_{up} (μm)
0	315	6	6	12	12	23	23
315	400	7	6	13	12	25	25
400	500	8	7	15	13	27	26
500	630	9	7	16	14	30	29
630	800	10	8	18	16	35	31
800	1000	11	9	21	17	40	35
1000	1250	13	10	24	19	46	39
1250	1600	15	11	29	22	54	44
1600	1800	-	-	35	25	65	51

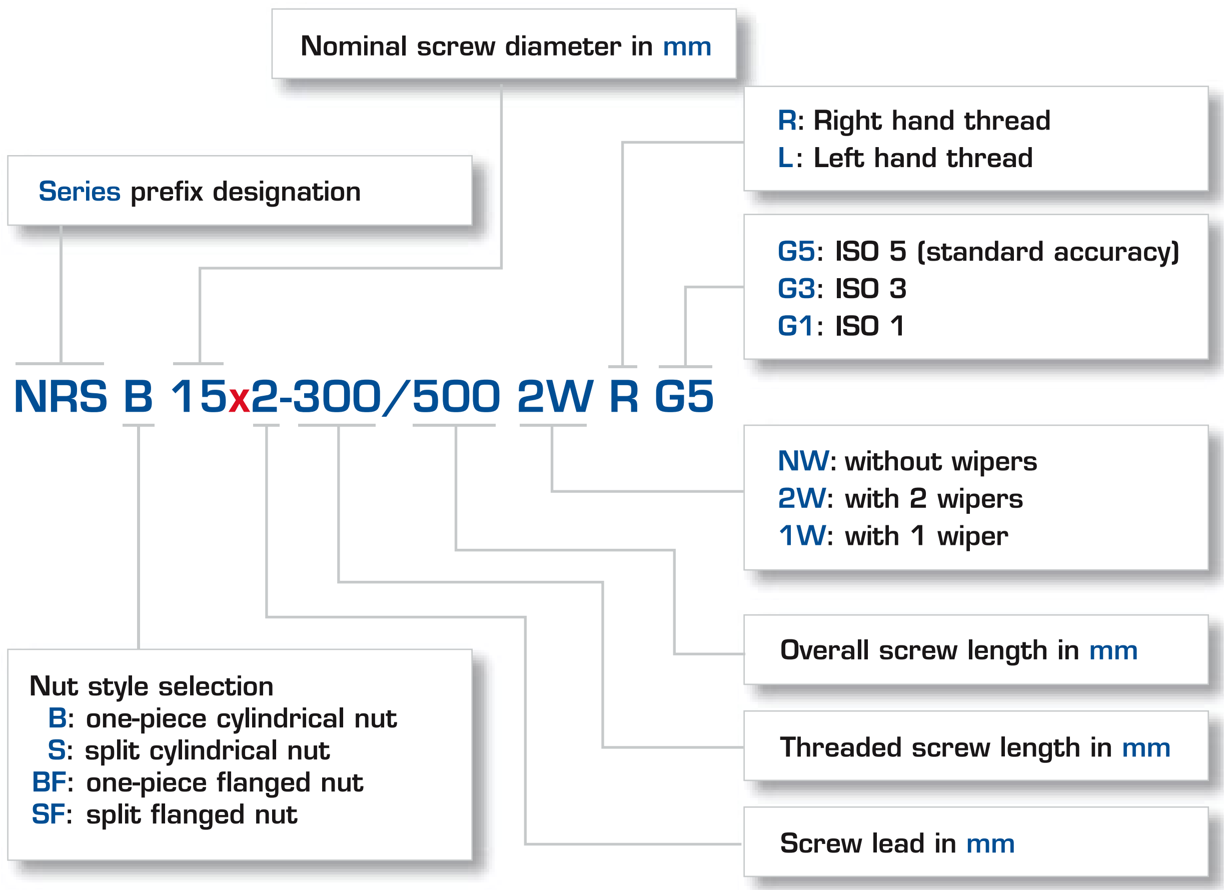
INSTALLATION

NRS planetary roller screws are precision components. They must be handled with care before and during installation to prevent the units from carrying radial loads or moments since either of these will impair the proper functioning and reduce the life of the system.

Nook engineers are at your disposal to address any concerns as to the design of the adjacent construction and the bearing arrangement to maximize the usefulness of the NRS planetary roller screws.

HOW TO ORDER

To generate a part number for ordering a NRS planetary roller screw assembly, specify the correct designations from the chart, see examples below. For further assistance contact our engineering department.



Examples:

NRS B 12x5-300/500 2W R G3

12x5 Right Hand Roller Screw, accuracy class of ISO 3, with a One-piece Cylindrical Nut with 2 wipers.
300mm of threaded screw with an overall length of 500mm.

NRS SF 30x25-1200/1600 NW L G1

30x25 Left Hand Roller Screw, accuracy class of ISO 1, with a Split Flanged Nut without wipers.
1200mm of threaded screw with an overall length of 1600mm.

EZRF and MKR:

To order a bearing support unit or a locknut include the part number (pages 18-19) as a line item with quantity specified.