ACCURACY STANDARDS & RECOMMENDATIONS

NOOK Precision Profile Rail Systems are available in six standard classes. The selected accuracy grade should match the positioning accuracy and parallelism requirements of the equipment.

The grade of the Profile Rail System should be matched to the ball screw if used.

ACCURACY STANDARDS						
Rail Accuracy Grade	**C001** Ultra Precision	**C01** Super Precision	**C1** Precision	**C3** High	**C5*** Standard	**C7** Commercial
Type H Accuracy	●	●	●	●	●	●
Type U Accuracy	●	●	●	●	●	●
ACCURACY OF ELEMENTS						
Height H** (unit: µm)						
Dimension Tolerance	±5	±10	±20	±40	±80	±200
Pair Variation	3	5	7	15	25	100
Width N** (unit: µm)						
Dimension Tolerance	±8	±15	±25	±50	±100	±200
Pair Variation	3	7	10	20	30	150

ACCURACY RECOMMENDATION OF BALL SCREWS AND PROFILE RAILS											
Ball Screw Accuracy Grade			**CO**		**C1**	**C2**	**C3**	**C4**	**C5**	**C7**	**C10**
Numerical Controlled Machines	Lathes	X	●	●	●	●	●				
		Z					●	●	●		
	Machining Centers	X			●	●	●	●			
		Y			●	●	●	●			
		Z				●	●	●	●		
	Grinding Machines	X	●	●	●	●					
		Z			●	●	●				
	EDM	X			●	●	●				
		Y			●	●	●				
		Z				●	●	●			
Semiconductor Manufacturing Equipment			●	●	●	●					
Non-CNC Machine Tools								●	●	●	●
General Industrial Machines										●	●

*Stocked Accuracy

**See Fig. 1 pg 7

See unit conversion on page 48

● = Available

ACCURACY

Please select the most suitable grade of NOOK Precision Profile Rail System for your application. For accuracy requirements beyond the tolerances indicated or for any special requirements, please contact NOOK application engineers.

Running Parallelism

Running Parallelism is defined as the error in the parallelism between the datum planes of the rail and the runner block as the runner block is moved along its entire travel length.

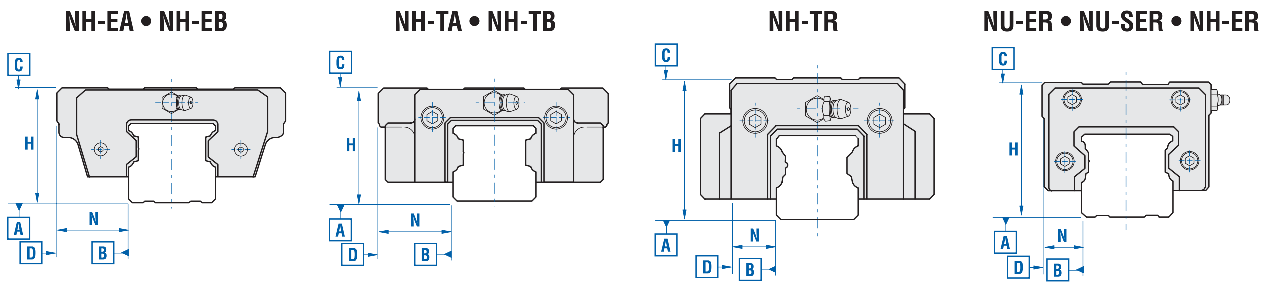
Differences in Height "H"

This defines the difference between the maximum and minimum heights "H" of the runner blocks that are mounted on the same rail. See figure 1. Accuracy class tolerance on page 6.

Difference in Widths "N"

This defines the difference between the maximum and minimum widths of "N" between each runner block mounted on the same rail. See figure 1. Accuracy class tolerance on page 6.

Fig. 1



Parallelism of plane [C] to datum plane [A]

Parallelism of plane [D] to datum plane [B]

Parallelism (unit: μm)

Rail Accuracy Grade / Rail Length Min (mm)	Max (mm)	C001 Ultra Precision	C01 Super Precision	C1 Precision	C3 High	C5* Standard	C7 Commercial
–	315	1.5	2	2.5	8	16	52
315	400	2	2.5	3.5	10	20	57
400	500	2	3	4.5	11	24	63
500	630	2	3.5	6	14	27	70
630	800	2.5	4	8	16	32	80
800	1000	3	4.5	9	19	38	90
1000	1250	3	6	11	22	43	105
1250	1600	4	7	14	25	50	125
1600	2000	4.5	8	16	29	57	150
2000	2500	6	9	18	30	60	170
2500	3150	6	10	18	30	60	210

* Stocked Accuracy

See unit conversion on page 48

RAIL LENGTH

The maximum lengths of rail for NOOK Precision Profile Rails are shown in the table below. Longer lengths can be achieved by butt joining rails.

Maximum length of rail track Unit: mm

Model No.	Max. Length
NH-15	3000
NU-15	1500
NH-20, 45, 55, 65	3000
NU-20 thru 55	
NH-25, 30, 35	4000

RAIL STRAIGHTNESS

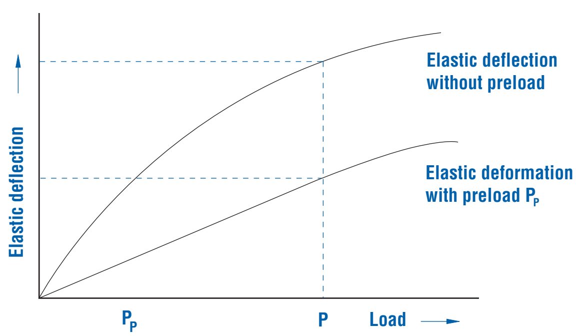
To obtain high accuracy guidance, the rail itself must be straight. It is very difficult to mount a distorted rail on a straight mounting surface. NOOK rail manufacturing processes ensure straightness for ease of assembly and long life. Distortion free end cuts are achieved through an automated, wet, abrasive cut-off saw system.

PRELOAD AND RIGIDITY

For correct operation under complex loading conditions, the selection of a suitable preload for linear motion bearings is essential. For extended life and accuracy under conditions of vibration and shock, the best results are usually achieved by using NOOK Precision Profile Rails with heavy preload.

In general, if preload is applied to the NOOK Precision Profile Rails, rigidity of the Profile Rail will be doubled compared to that of a non-preloaded Profile Rail.

The preloaded condition is effective for operating loads of up to approximately 3 times the value of preload. Therefore, as a guide, one half to one third of the operating load should be considered for preload and specified according to tables below.



Standard preload (Unit: kgf)

Runner Block & Style			Preload				
NH-L	NH NU	NU-SER	T	TO*	T1	T2	T3
		15	-	0	15	30	45
	15	20	-	0	25	50	75
			-	0	30	60	90
	20	25	-	0	40	80	120
			-	0	50	I00	150
	25	30	-	0	55	110	165
25			-	0	70	140	210
	30	35	-	0	80	160	240
30			-	0	95	190	285
	35		-	0	110	220	330
			-	0	120	240	360
35			-	0	135	270	405
	45		-	0	180	360	540
45			-	0	210	420	630
	55		-	0	270	540	810
55			-	0	310	620	930
	65		-	0	420	840	1260
65			-	0	520	1040	1560

Radial clearance of non-preload type (T) is max. 0.02 mm

*Stocked Preload

See unit conversion on page 48

Selection of preload

Preload	Conditions of use	Application
T3 Heavy **T2** Medium	Heavy cutting or forming work with heavy impact and vibration. Overhung load or alternate load applied.	• Machining center • Milling machines • Vertical axis of machine tools
T2 Medium **T1** Light	Medium cutting or forming Light work with medium impact and vibration. Light overhung load or alternate load applied.	• Electrical discharge machines • Surface grinding machines • Robots. • Jig grinding machines • Laser processing machines • Printed circuit board drilling machines. • High speed punching machines.
T1 Light **TO** Very Light	Precise movement with very light vibration. No overhung load or no alternate load applied.	• Precision positioning tables • Tables of optical measuring equipment • Automatic Tool Changer for machining centers • Welding machines • Material feeding devices
TO Very Light **T** Clearance	Extreme changes in temperature. High precision not required.	• Tool changers Material feeding devices • Plasma cutting machines

LIFE

All of the following factors should be taken into consideration when selecting a NOOK Precision Profile Rail System:

The rolling elements and raceways of a NOOK Precision Profile Rail System that support a load are always subject to cyclic stress. Eventually, part of the raceway may spall due to metal fatigue. The life of a linear motion system is defined as the total distance of the travel reached by the time that first fatigue spalling occurs, either from a rolling element or raceway.

1. Definition of Rated Load

- **Dynamic load ratings C**

  C (kN) is the operating load which specifies 50km of travel. (1 kgf=9.81 Newtons=0.2248 lbf)

- **Static load ratings C_0**

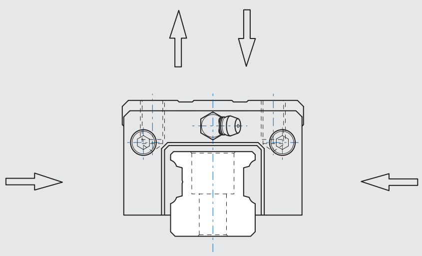
  C_0 (kN) is the load that causes a permanent deformation equal to 1/10000 of the ball diameter at the contact point between the ball groove and the steel ball.

- **Static moment ratings M**

  M (kN-m) is the moment which causes a permanent deformation equal to 1/10000 of the ball diameter at the contact point between the ball groove and the steel ball when a moment load is applied.

  For C, C_0, M of each model refer to dimensional table.

NOOK Precision Profile Rails have the same dynamic load capacity in four directions: radial, reverse-radial and bi-lateral.



2. Static Safety Factor

Generally, the maximum permitted static load on the runner block is equivalent to static load ratings C_0. However, in repeated linear motion applications, unexpected load is caused by the inertia when the system starts or stops. Therefore, the safety factor **fs** should be calculated in order to determine the allowable load.

$$\frac{C_0}{P_0} \geqq fs$$

C_0 = static load ratings
P_0 = equivalent load
(static load, impact load)
fs = static safety factor

The value of fs for general use is indicated in the table.

Static Safety Factor

Operating condition	Minimum fs
Normal operation	1~3
Smooth running required	3~4
Operation with impact or vibration	4~5

3. Determination of Rated Fatigue Life

Dynamic load ratings C (kN), number of strokes per minute and rated fatigue life L (km) are related as follows:

$$L = 50 \times \left(\frac{C}{P}\right)^3$$

L = expected life
C = basic load ratings
P = equivalent load

Where the stroke ℓs (m) and the number of cycles per minute n_1 (cpm) are constant, the rated fatigue life Lh (hr) is calculated by the following formula.

$$L_h = \frac{50 \times 10^3}{120 \times \ell s \times n_1} \times \left(\frac{C}{P}\right)^3$$

L_h = expected Life (hr)
ℓs = stroke length (m)
n_1 = number of strokes per minute

4. Calculation of Runner Block Load

- **Driving factor and contact factor**

The load acting upon the runner block is the sum of all of the loads applied such as the weight of the table, the cutting force and the inertia force caused by the change of speed or by heavy impact or vibration.

Loads other than the weight of the table are often difficult to calculate. If in doubt, the applied load should be multiplied by a driving factor **fd** (table below) to give the effective external load.

Driving factor fd

Operating condition	fd
Smooth running without impact. Speed under 15 m/min.	l.0~ l .5
Running with light impact. Speed under 60 m/min.	l.5~ 2.0
Running with heavy impact. Speed over 60 m/min.	2.0~4.0

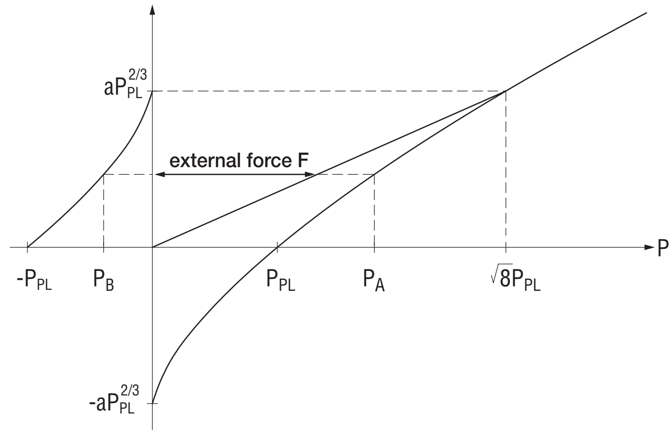
In most installations each rail is fitted with at least two runner blocks. The distribution of load across each runner block is very much influenced by the mounting accuracy or machining accuracy of the table. Therefore, the contact factor in the table below should be taken into account.

Contact factor fc

Number of runner blocks on one rail	fc
1	1.00
2	0.86
3	0.74
4	0.66

- **Effect of preload on internal load of runner block**

Internal load P_A is determined by external force F and preload of runner block P_{PL}.



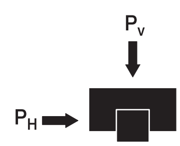
1) Where $F \leqq \sqrt{8}\,P_{PL}$
   internal load $P_A = \left(\frac{F}{\sqrt{8}\,P_{PL}} + 1\right)$

2) Where $F > \sqrt{8}\,P_{PL}$
   internal force $P_A = F$

- **Resultant force of vertical load and horizontal load**

Resultant force of vertical load P_v and horizontal load P_H is determined as follows:

$$P = P_V + P_H$$

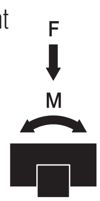


- **Resultant force of radial load and moment load**

Resultant force of radial load F and moment load M is determined as follows.

$$\Sigma F + \left(\frac{M \times C_0}{M_c \times 10^3}\right)$$

C_0 = rated static load
M_c = rated static torque on M direction
M = applied moment



See unit conversion on page 48

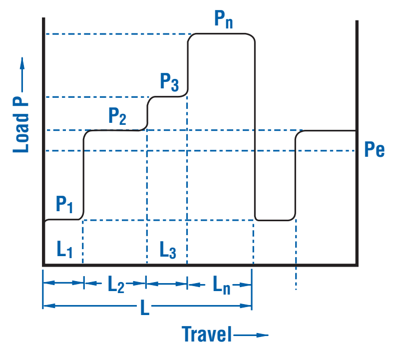
- **Mean load vs. load variation**

  In applications where the load onto the runner block varies, mean load should be considered instead of discrete load variations P_1, P_2...P_n.

  1) For cases where the load and travel vary gradually:

$$P_e = \sqrt[3]{\frac{1}{L}\left(P_1^3L_1+P_2^3L_2+\ldots\ldots+P_n^3L_n\right)}$$

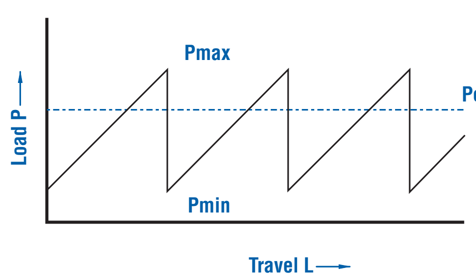
P_e = mean load (kN)
P_n = load step (kN)
L = total travel (m)
L_n = distance travelled by P_n (m)



2) For cases where the load vary abruptly:

$$P_e = \frac{2P_{max} + P_{min}}{3}$$

P_{min}: min. load (kN)
P_{max}: max. load (kN)



3) Sinusoidal load change:

$P_e \approx 0.65\ P_{max}$ (Fig.A)
$P_e \approx 0.75\ P_{max}$ (Fig.B)

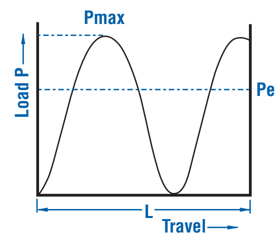


Fig. A

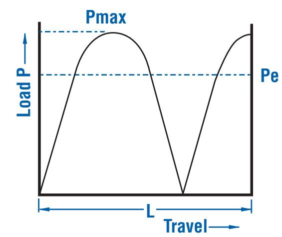


Fig. B

- **Frictional resistance**

  For correct load calculation, frictional resistance of the runner block must be included. Frictional resistance is calculated using the following formula.

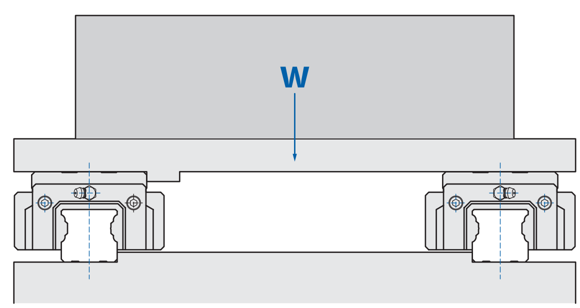
$F = \mu W + f$

F = frictional resistance force (kN)
W = slide load (kN)
μ = coefficient of friction
f = seal resistance force (kN)

The coefficient of friction for NOOK Precision Profile Rails is typically 0.003~0.005 with no preload. Seal resistance force per runner block is typically .00196~.002942 kN.

Example: For a slide load (W) of 15.69 kN on 4 runner blocks of NH- TR model, the frictional resistance (F) is calculated:

$F = \mu W + f$
$= (0.004 \times 15.69) + (0.3 \times 4) = .0745$ kN

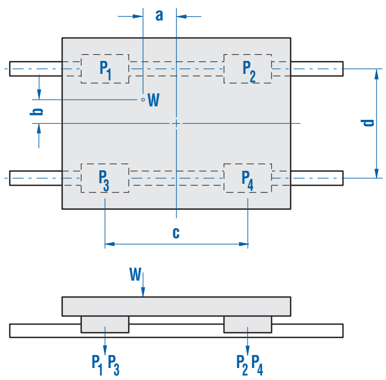


See unit conversion on page 48

- **Load on the runner block**

The loads acting on a linear motion system vary according to the location of the center of gravity, the thrust, position, moment, loading speed changes by acceleration and deceleration, cutting forces and other external forces. It is important that all of these parameters are considered at the design stage.

Horizontal Axis



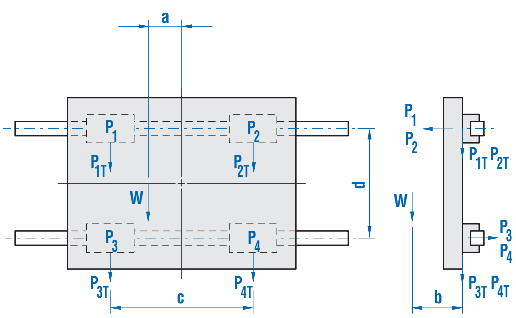
$$P_1 = \frac{1}{4}W + \frac{a}{2c}W + \frac{b}{2d}W$$

$$P_2 = \frac{1}{4}W - \frac{a}{2c}W + \frac{b}{2d}W$$

$$P_3 = \frac{1}{4}W + \frac{a}{2c}W - \frac{b}{2d}W$$

$$P_4 = \frac{1}{4}W - \frac{a}{2c}W - \frac{b}{2d}W$$

Perpendicular Horizontal Axis

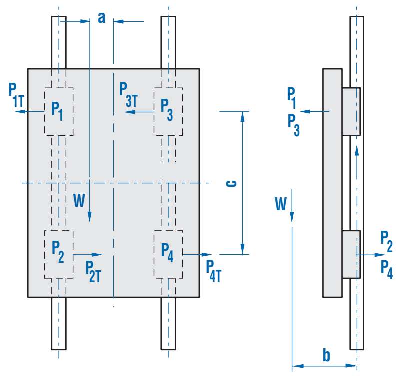


$$P_1 = P_2 = P_3 = P_4 = \frac{b}{2d}W$$

$$P_{1T} = P_{3T} = \frac{1}{4}W + \frac{a}{2c}W$$

$$P_{2T} = P_{4T} = \frac{1}{4}W - \frac{a}{2c}W$$

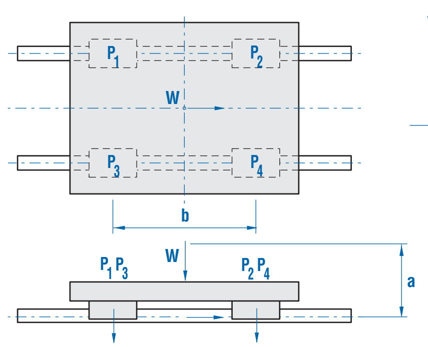
Vertical Axis

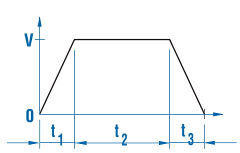


$$P_1 = P_2 = P_3 = P_4 = \frac{b}{2c}W$$

$$P_{1T} = P_{2T} = P_{3T} = P_{4T} = \frac{a}{2c}W$$

Acceleration Deceleration





$$P_1 = P_3 = \frac{1}{4}W + \frac{a}{2b}\frac{V}{gt_1}W$$

$$P_2 = P_4 = \frac{1}{4}W - \frac{a}{2b}\frac{V}{gt_1}W$$

- While accelerating

$$P_1 = P_2 = P_3 = P_4 = \frac{1}{4}W$$

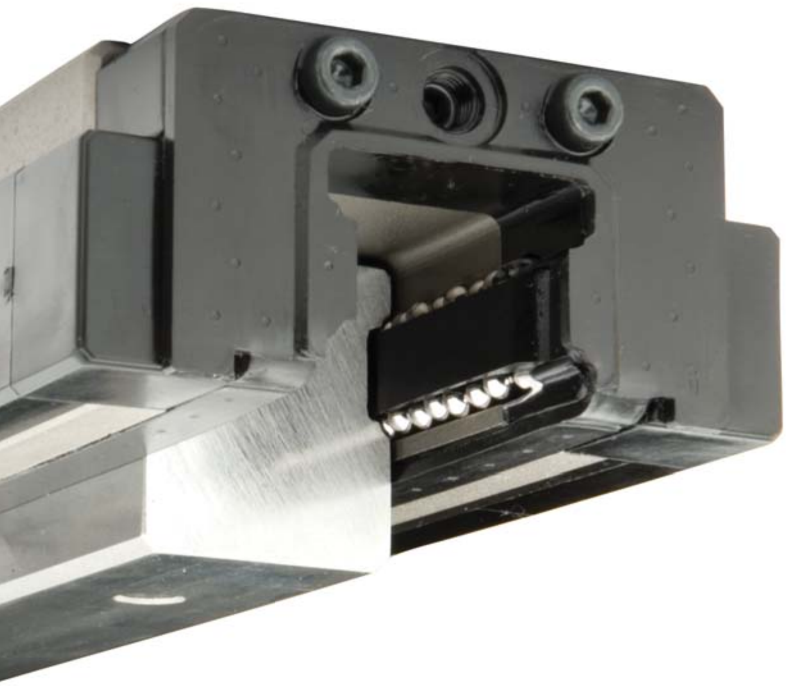
- While at a steady-state speed

$$P_1 = P_3 = \frac{1}{4}W - \frac{a}{2b}\frac{V}{gt_3}W$$

$$P_2 = P_4 = \frac{1}{4}W + \frac{a}{2b}\frac{V}{gt_3}W$$

- While decelerating

g: Gravitational Constant = 9.81 m/s^2



5. Calculation Example

- **Determination of RUNNER BLOCK LIFE**
  A sample calculation of runner block life is shown below.

Model NH35TR
Stroke, ℓs = 1m
Load, W = 9.8 kN
Driving factor, fd = 1.2

Contact factor, fc = 0.86
2 rails, 4 runner blocks
No. of cycles, n_1 = 5 cpm

$$P_1 = \frac{fd}{fc}\left(\frac{W}{4} - \frac{100W}{2 \times 800} + \frac{200W}{2 \times 1200}\right) = 3.70 \text{ kN}$$

$$P_2 = \frac{fd}{fc}\left(\frac{W}{4} + \frac{100W}{2 \times 800} + \frac{200W}{2 \times 1200}\right) = 5.41 \text{ kN}$$

$$P_3 = \frac{fd}{fc}\left(\frac{W}{4} - \frac{100W}{2 \times 800} - \frac{200W}{2 \times 1200}\right) = 1.42 \text{ kN}$$

$$P_4 = \frac{fd}{fc}\left(\frac{W}{4} + \frac{100W}{2 \times 800} - \frac{200W}{2 \times 1200}\right) = 3.13 \text{ kN}$$

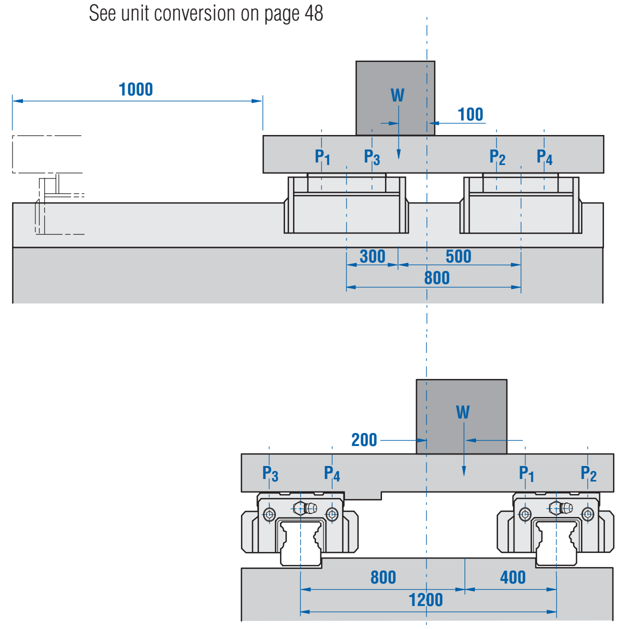
Life of the No.1 runner block which experiences the highest load is determined from C=37.55 kN obtained from the dimension table (page 37).

$$L = 50 \times \left(\frac{37.55}{5.39}\right)^3 = 16{,}719 \text{ km}$$

The life in hours can be calculated

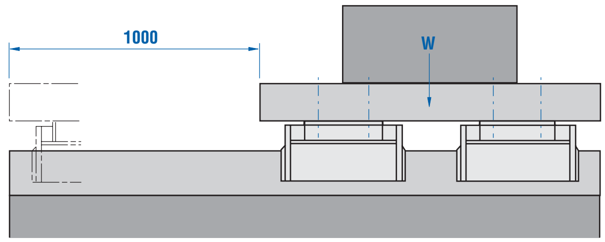
$$L_h = \frac{L \times 10^3}{120 \times \ell_s \times n_1} = 27{,}865 \text{ hr}$$

See unit conversion on page 48



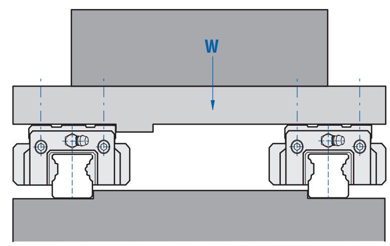
- ## Selection of a suitable Profile Rail Assembly as a function of required life

A sample selection is shown below using the following criteria:



Stroke	$\ell s = 1m$
No. of strokes per minute	$n_1 = 5$ cpm (10m/min)
Expected life	$L_h = 25000$ hr
Load	W = 19.61 kN
Driving factor	fd = 1.5
Contact factor	fc = 0.86
from (1) (2)	

$$L = \frac{120 \times \ell s \times n_1}{10^3} \times L_h = \frac{120 \times 1 \times 5}{10^3} \times 25000 = 15000 \text{ km}$$



Load per bearing

$$P = \frac{fd}{fc} \times \frac{W}{4} = \frac{1.5}{0.86} \times \frac{19.61}{4} = 8.55 \text{ kN}$$

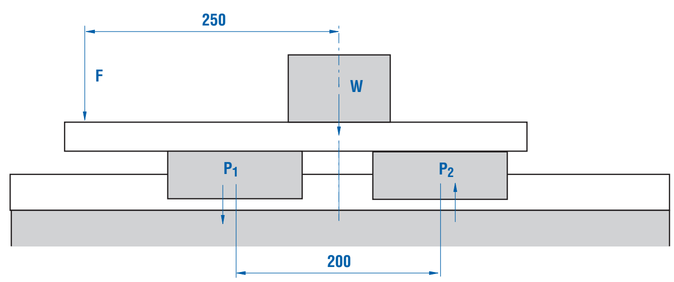
from equation (1)

$$C = P \times \sqrt[3]{\frac{L}{50}} = 8.55 \times \sqrt[3]{\frac{15000}{50}} = 57.24 \text{ kN}$$

NH45TR (C=60.20 kN) which has the required dynamic load rating is selected from the dimension table (page 37).

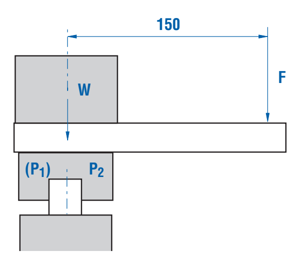
- ## Determination of runner block life (single axis)

A sample selection is shown below using the following criteria:



Model NH35TR	
Rated dynamic load capacity	C = 37.55 kN
Rated static load capacity	$C_0 = 62.55$ kN
Static mount rating M_C	$M_C = 1.13$ N•M
Load	W = 1.96 kN
External force	F = .196 kN
Driving factor	fd = 1.4

$$P_1 = P_2 = \frac{fd}{fc}\left(\frac{W}{2} + \frac{F}{2} + \frac{F \times 250}{200} + \left(\frac{F \times 150 \times C_0}{2 \times M_c \times 10^3}\right)\right) = 3.48 \text{ kN}$$



Life of runner block (L) which is subjected to load P_1 is:

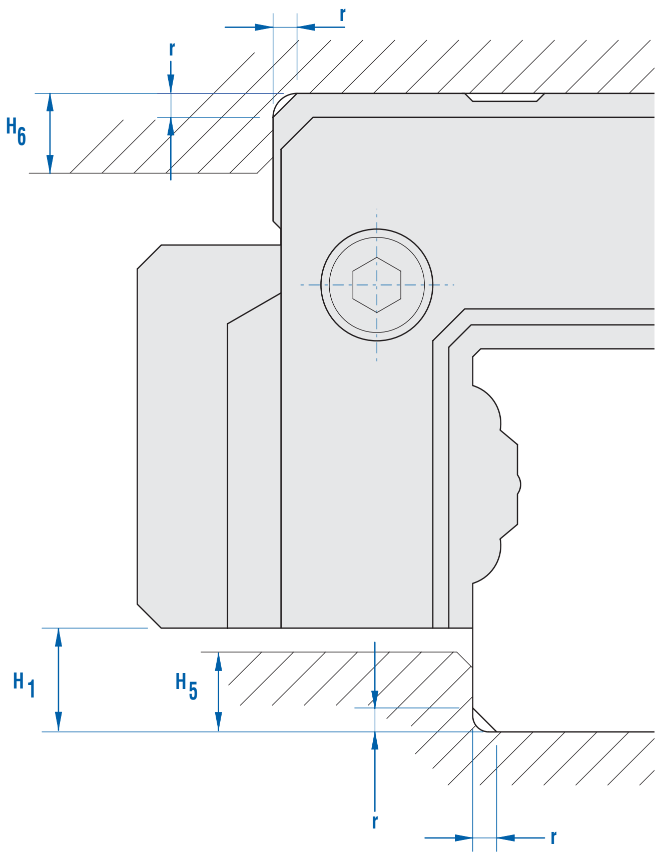
$$L = 50 \times \left(\frac{C}{P_1 \times fd}\right)^3 = 32{,}070 \text{ km}$$

See unit conversion on page 48

DESIGN RECOMMENDATIONS/GUIDELINES

1. Mounting Shoulder Height and Corner Fillet

In order to provide a register to align the rail or the runner blocks, mounting surfaces should be machined according to the diagram below with shoulder height and corner radii dimensions as shown in the accompanying table.

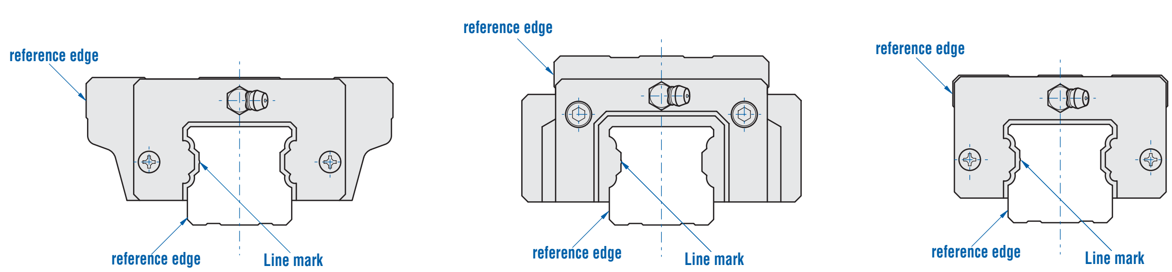


Mounting Shoulder Height and Corner Fillet Unit: mm

Model No.	Corner Radius r (max)	Rail Track Shoulder Height H_5	Slide Unit Shoulder Height H_6	H_1
NH-15 NU-15	0.5	4	4	4.6
NU-20	0.5	3	4	4
NH-20	0.5	4	4	5
NU-25	0.5	3	5	4
NH-25	0.5	5	5	6.5
NH-30 NU-30	0.5	5	5	7
NH-35 NU-35	1.0	6	6	8
NH-45 NU-45	1.0	8	8	11
NU-55	1.0	9	0	12
NH-55	1.0	10	10	14
NH-65	1.0	10	10	14

2. Indication of Reference Edge

NOOK Precision Profile Rails have a reference edge on both the rail and the runner block. See below.



See unit conversion on page 48

3. Installation of Rail and Runner Blocks

Use any one of the three methods shown below.

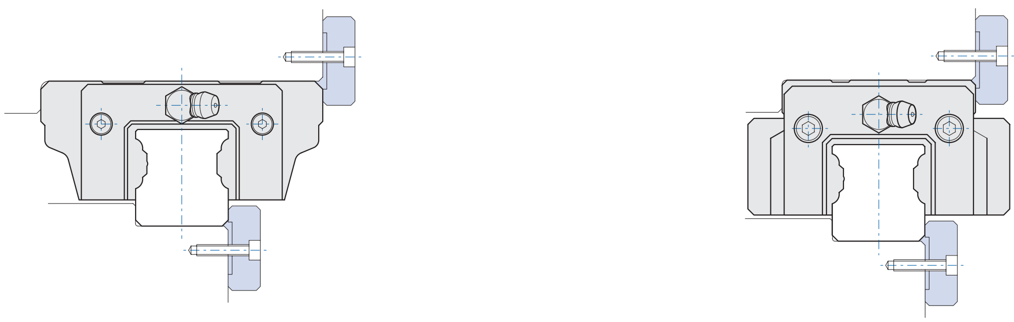
The locking set screws should be positioned at the same location as the mounting bolts.

Better alignment is obtained by machining reference edges for both runner block and rail. For optimum performance, the accuracy of the mounting surface should equal that of the rail.

Note: Care should be taken when removing the runner block from the rail to avoid balls deflecting the ball retainers and thus falling out.

1) Set Screw

2) Clamps



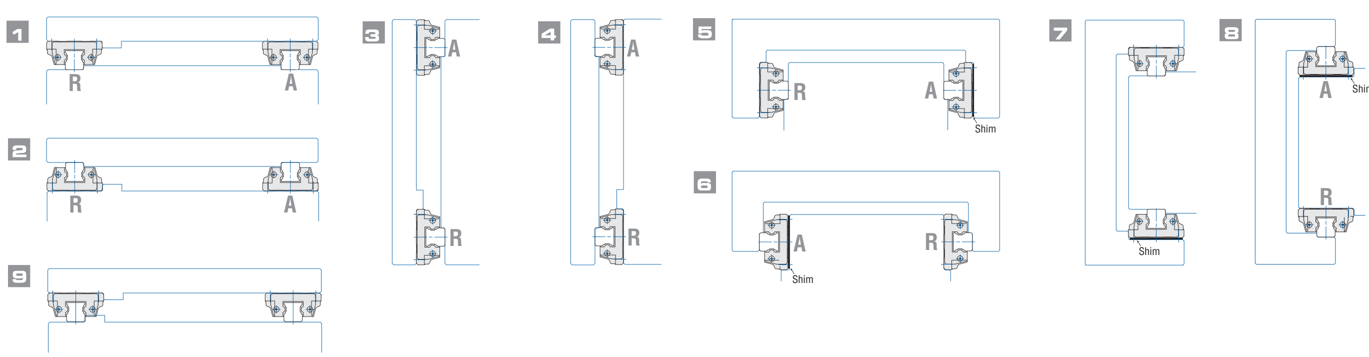
3) Tapered Wedges

4. System Design Configurations for Nook Precision Profile Rails

Shown below are various installations for profile rail systems. One through four are the most common. Five through eight are for limited height applications. Number nine is the least accurate.

	Horizontal	Vertical	Opposing Horizontal	Opposing Vertical
Rail Track Fixed	1, 9	3	5	7
Runner Block Fixed	2	4	6	8

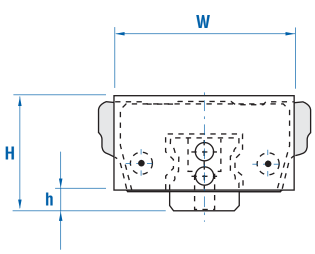
See examples below: A= Adjustable Side • R= Reference Side

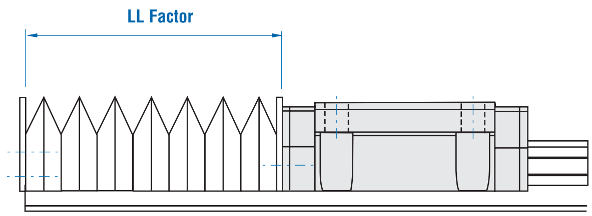


BELLOW COVERS

When additional protection is required the use of NOOK bellows is recommended. The chart below indicates the bellows dimensions.

PVC coated polyester material is used exclusively. Neoprene-cloth and chemically resistant materials are also available upon request.





Unit: mm

Bellow Model No.	Profile Rail Model No.	W	H	h	Above or Below Block	LL Factor
JS15	NH-15 EA	48	24.5	5	Above 6mm	1.28
	NH-15 ER	41	23.5	5	Above 6mm	
JS20	NH-20 EA	51	28	5	Above 3mm	1.28
	NU-20 ER	46	26.5	4	Above 4mm	
JS25	NH-25 EA	51	28	7	Even	1.28
	NU-25 ER	47	28.5	4	Above 1mm	
JS30	NH-30 EA	58	35	7	Even	1.20
	NU-30 ER	60	35	7	Even	
JS35	NH-35 EA	72	40	8	Even	1.17
	NU-35 ER	70	40	8	Even	
JS45	NH-45 EA	83	45	11	Even	1.17
	NU-45 ER	81	47	11	Even	
JS55	NH-55 EA	100	55	14	Even	1.13
	NU-55 ER	100	55	12	Even	
JS65	NH-65 EA	117	68	14	Even	1.11

*Add 10mm to bellow compressed length for hardware

See unit conversion on page 48

LL FACTOR CALCULATIONS

Maximum Extended Length (Lmax) = Stroke x Nook LL Factor
Minimum Collapsed Length (Lmin) = Maximum Extended Length – Stroke

Example:

For a Rail Cover for a Nook-NH65. The Rail Cover is Nook-NH65

Stroke = 10” and LL Factor = 1.11

Convert to metric since most calculations are in metric.

Stroke = 10 x 25.4 = 254.00mm

Maximum extended length = 254 x 1.11 = 281.94mm

Round off to the next full number Lmax – Stroke

Minimum Collapsed Length (Lmin) = Lmax – Stroke

Lmin = 282.00 – 254.00 = 28.00mm

Summary:

For Nook-NH65 Rail Cover using PVC-Poly Material

Stroke = 254.00mm

Lmax = 282.00mm

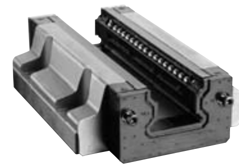
Lmin = 28.00mm

ACCESSORIES AND LUBRICATION

Proper lubrication and contamination protection are an essential requirement for NOOK Precision Profile Rails.

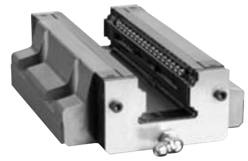
Seal

A standard feature of NOOK runner blocks is a special composite rubber seal on both ends of the block that effectively retains grease (lithium soap base) within the runner block. This seal also acts to keep out many contaminants.



Scrapers

Stainless scraper plate option for enhanced protection of the seal as well as removal of contaminant build up such as light weld spatter and overspray.



Mounting Hole Caps

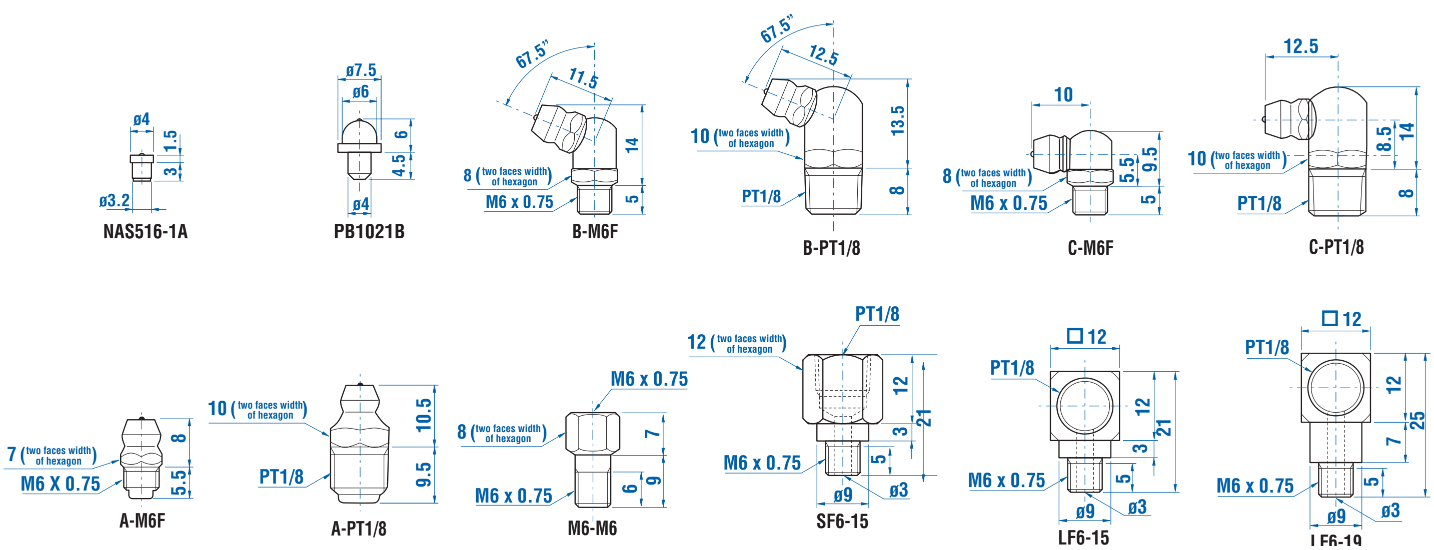
For sealing quality and protection use the cap plugs supplied by NOOK to cover the mounting holes in the rail flush with the top surface.

Grease Gun

Refillable and reusable push style grease gun for lubricating size 15 block. Ships empty to allow for application specific grease.

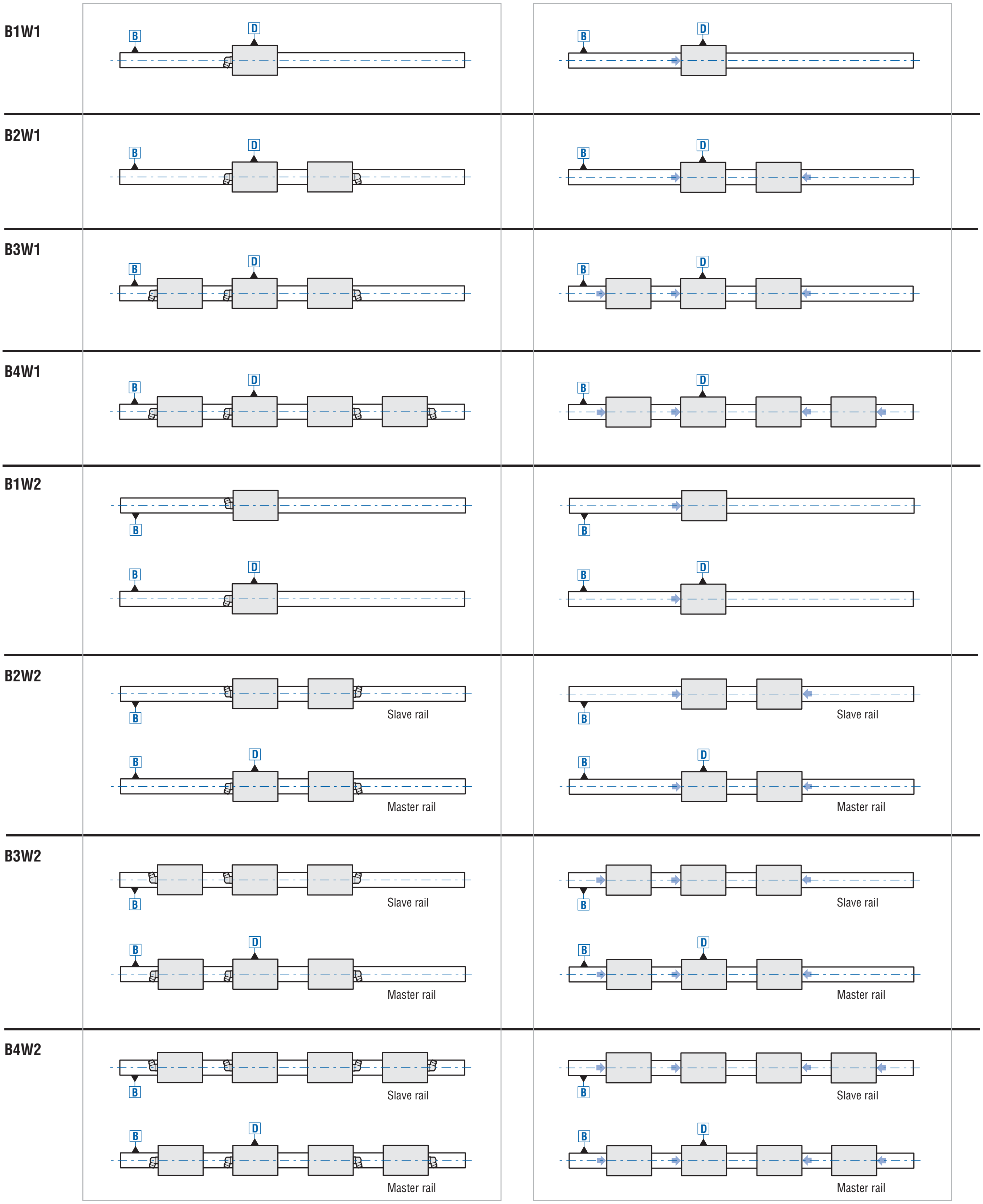
Grease Fittings

Lubrication is recommended every six months or after every 100km (about 330,000 ft.) of travel. If lubrication every six months or 100km is not practical, forced oil lubrication is necessary. Refer to the catalog pages for the runner block types to determine the style of grease fitting supplied.



ORIENTATION OF REFERENCE SURFACE AND GREASE FITTING - STANDARD POSITION

In case of L (external) type fitting: | **In case of I (internal) type fitting:**



➡ shows direction of feeding