Preface

A linear guideway allows a type of linear motion that utilizes rolling elements such as balls or rollers. By using re-circulating rolling elements between the rail and the block, a linear guideway can achieve high precision linear motion. Compared to a traditional slide, the coefficient of friction for a linear guideway is only 1/50th. Because of the restraint effect between the rails and the blocks, linear guideways can take up loads in both the up/down and the left/right directions. With these features, linear guideways can greatly enhance moving accuracy, especially, when accompanied with precision ball screws.

1. General Information

1-1 Advantages and Features of Linear Guideways

(1) High positional accuracy
When a load is driven by a linear motion guideway, the frictional contact between the load and the bed is rolling contact. The coefficient of friction is only 1/50th of traditional contact, and the difference between the dynamic and the static coefficient of friction is small. Therefore, there would be no slippage while the load is moving.

(2) Long life with high motion accuracy
With a traditional slide, errors in accuracy are caused by the counter flow of the oil film. Insufficient lubrication causes wear between the contact surfaces, which become increasingly inaccurate. In contrast, rolling contact has little wear; therefore, machines can achieve a long life with highly accurate motion.

(3) High speed motion is possible with a low driving force
Because linear guideways have little friction resistance, only a small driving force is needed to move a load. This results in greater power savings, especially in the moving parts of a system. This is especially true for the reciprocating parts.

(4) Equal loading capacity in all directions
With this special design, these linear guideways can take loads in either the vertical or horizontal directions. Conventional linear slides can only take small loads in the direction parallel to the contact surface. They are also more likely to become inaccurate when they are subjected to these loads.

(5) Easy installation
Installing a linear guideway is fairly easy. Grinding or milling the machine surface, following a recommended installation procedure, and tightening the bolts to their specified torque can achieve highly accurate linear motion.

(6) Easy lubrication
With a traditional sliding system, insufficient lubrication causes wear on the contact surfaces. Also, it can be quite difficult to supply sufficient lubrication to the contact surfaces because finding an appropriate lubrication point is not very easy. With a linear motion guideway, grease can be easily supplied through the grease nipple on the linear guideway block. It is also possible to utilize a centralized oil lubrication system by piping the lubrication oil to the piping joint.

(7) Interchangeability
Compared with traditional boxways or v-groove slides, linear guideways can be easily replaced should any damage occur. For high precision grades consider ordering a matched, non-interchangeable, assembly of a block and rail.

Linear Guideways

General Information

1-2 Selecting Linear Guideways

Identify the condition
- Type of equipment
- Space limitations
- Accuracy
- Stiffness
- Travel length
- Magnitude and direction of loads
- Moving speed, acceleration
- Duty cycle
- Service life
- Environment

Selection of series
- HG series - Grinding, milling, and drilling machine, lathe, machine center
- EG series - Automatic equipment, high speed transfer device, semiconductor equipment, wood cutting machine, precision measure equipment
- MGN/MGW series - Miniature device, semiconductor equipment, medical equipment

Selection of accuracy
- Classes : C, H, P, SP, UP depends on the accuracy of equipment

Determines the size & the number of blocks
- Dynamic load condition
- If accompanied with a ballscrew, the size should be similar to the diameter of ballscrew. For example, if the diameter of the ballscrew is 35mm, then the model size of linear guideway should be HG35

Calculate the max. load of block
- Make reference to load calculation examples, and calculate the max load.
- Be sure that the static safety factor of selected guideway is larger than the rated static safety factor

Choosing preload
- Depends on the stiffness requirement and accuracy of mounting surface

Identify stiffness
- Calculate the deformation (δ) by using the table of stiffness values, choosing heavier preload and larger size linear guideways to enhance the stiffness

Calculating service life
- Calculate the life time requirement by using the moving speed and frequency.
- Make reference to the life calculation example

Selection of lubrication
- Grease supplied by grease nipple
- Oil supplied by piping joint

Completion of selection

1-3 Basic Load Ratings of Linear Guideways

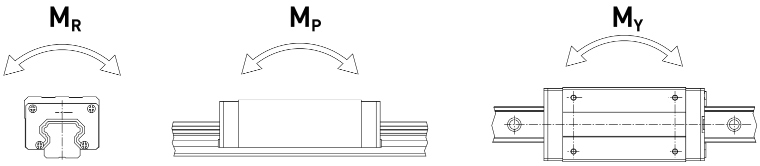
1-3-1 Basic Static Load

(1) Static load rating (C_0)

Localized permanent deformation will be caused between the raceway surface and the rolling elements when a linear guideway is subjected to an excessively large load or an impact load while either at rest or in motion. If the amount of this permanent deformation exceeds a certain limit, it becomes an obstacle to the smooth operation of the linear guideway. Generally, the definition of the basic static load rating is a static load of constant magnitude and direction resulting in a total permanent deformation of 0.0001 times the diameter of the rolling element and the raceway at the contact point subjected to the largest stress. The value is described in the dimension tables for each linear guideway. A designer can select a suitable linear guideway by referring to these tables. The maximum static load applied to a linear guideway must not exceed the basic static load rating.

(2) Static permissible moment (M_0)

The static permissible moment refers to a moment in a given direction and magnitude when the largest stress of the rolling elements in an applied system equals the stress induced by the Static Load Rating. The static permissible moment in linear motion systems is defined for three directions: M_R, M_P and M_Y.



(3) Static safety factor

This condition applys when the guideway system is static or under low speed motion. The static safety factor, which depends on environmental and operating conditions, must be taken into consideration. A larger safety factor is especially important for guideways subject to impact loads (See Table 1.1). The static load can be obtained by using Eq. 1.

Table 1.1 **Static Safety Factor**

Load Condition	f_{SL} , f_{SM} (Min.)
Normal Load	1.0~3.0
With impacts/vibrations	3.0~5.0

$$f_{SL} = \frac{C_0}{P} \text{ or } f_{SM} = \frac{M_0}{M} \qquad \text{Eq.1.1}$$

f_{SL} : Static safety factor for simple load
f_{SM} : Static safety factor for moment
C_0 : Static load rating (kN)
M_0 : Static permissible moment (kN•mm)
P : Calculated working load (kN)
M : Calculated appling moment (kN•mm)

1-3-2 Basic Dynamic Load

(1) Dynamic load rating (C)

The basic dynamic load rating is the load that does not change in direction or magnitude and results in a nominal life of 50km of operation for a linear guideway. The values for the basic dynamic load rating of each guideway are shown in dimension tables. They can be used to predict the service life for a selected linear guideway.

Linear Guideways
General Information

1-4 Service Life of Linear Guideways

1-4-1 Service Life

When the raceway and the rolling elements of a linear guideway are continuously subjected to repeated stresses, the raceway surface shows fatigue. Flaking will eventually occur. This is called fatigue flaking. The life of a linear guideway is defined as the total distance traveled until fatigue flaking appears on the surface of the raceway or rolling elements.

1-4-2 Nominal Life (L)

The service life varies greatly even when the linear motion guideways are manufactured in the same way or operated under the same motion conditions. For this reason, nominal life is used as the criteria for predicting the service life of a linear motion guideway. The nominal life is the total distance that 90% of a group of identical linear motion guideways, operated under identical conditions, can travel without flaking. When the basic dynamic rated load is applied to a linear motion guideway, the nominal life is 50km.

1-4-3 Calculation of Nominal Life

The acting load will affect the nominal life of a linear guideway. Based on the selected basic dynamic rated load and the actual load, the nominal life can be calculated by using Eq. 1.2.

$$L=\left(\frac{C}{P}\right)^3 \cdot 50\text{km}=\left(\frac{C}{P}\right)^3 \cdot 31\text{mile} \qquad \text{Eq.1.2}$$

L : Nominal life
C : Basic dynamic load rating
P : Actual load

If the environmental factors are taken into consideration, the nominal life is influenced greatly by the motion conditions, the hardness of the raceway, and the temperature of the linear guideway. The relationship between these factors is expressed in Eq. 1.3.

$$L=\left(\frac{f_h \cdot f_t \cdot C}{f_w \cdot P_c}\right)^3 \cdot 50\text{km}=\left(\frac{f_h \cdot f_t \cdot C}{f_w \cdot P_c}\right)^3 \cdot 31\text{mile} \qquad \text{Eq.1.3}$$

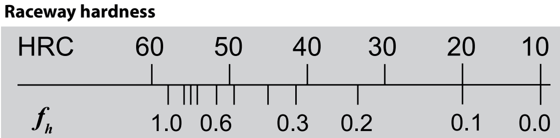
L : Nominal life
f_h : Hardness factor
C : Basic dynamic load rating
f_t : Temperature factor
P_C : Calculated load
f_W : Load factor

1-4-4 Factors of Normal Life

(1) Hardness factor (f_h)

In general, the raceway surface in contact with the rolling elements must have the hardness of HRC 58~62 to an appropriate depth. When the specified hardness is not obtained, the permissible load is reduced and the nominal life is decreased. In this situation, the basic dynamic load rating and the basic static load rating must be multiplied by the hardness factor for calculation.

Raceway hardness



(2) Temperature factor (f_t)

When the temperature of a linear guideway exceeds 100°C, the permissible load is reduced and the nominal life is decreased. Therefore, the basic dynamic load rating and the basic static load rating must be multiplied by the temperature factor.

Temperature

(3) Load factor (f_w)

The loads acting on a linear guideway include the weight of slide, the inertia load at the times of start and stop, and the moment loads caused by overhanging. These load factors are especially difficult to estimate because of mechanical vibrations and impacts. Therefore, the load on a linear guideway should be divided by the empircal factor.

Table 1.2 **Load factor**

HG/EG Series

Loading Condition	Service Speed	f_w
No impacts & vibration	V≦15 m/min	1 ~ 1.2
Small impacts	15 m/min <V≦60 m/min	1.2 ~ 1.5
Normal load	60m/min< V≦ 120 m/min	1.5 ~ 2.0
With impacts & vibration	V >120 m/min	2.0 ~ 3.5

MG Series

Loading Condition	Service Speed	f_w
No impacts & vibration	V≦15 m/min	1 ~ 1.5
Normal load	15m/min <V≦60 m/min	1.5 ~ 2.0
With impacts & vibration	V >60 m/min	2.0 ~ 3.5

1-4-5 Calculation of Service Life (L_h)

Transform the nominal life into the service life time by using speed and frequency.

$$L_h = \frac{L \cdot 10^3}{V_e \cdot 60} = \frac{\left(\frac{C}{P}\right)^3 \cdot 50 \cdot 10^3}{V_e \cdot 60} \text{ hr} \qquad \text{Eq.1.4}$$

L_h : Service life (hr)
L : Nominal life (km)
V_e : Speed (m/min)
C/P : Load factor

1-5 Applied Loads

1-5-1 Calculation of Load

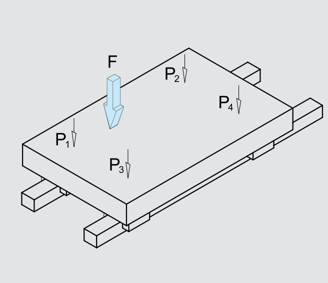
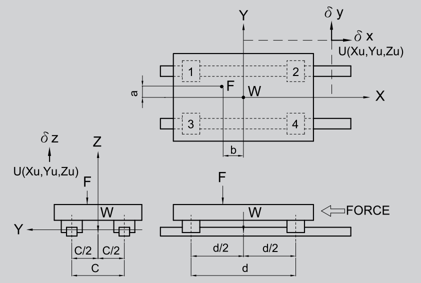
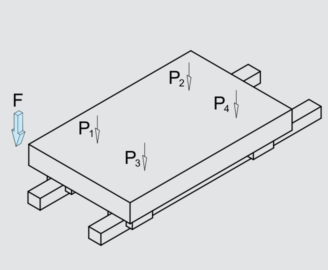
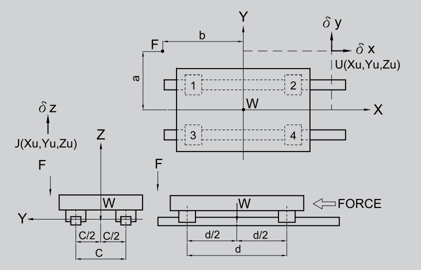
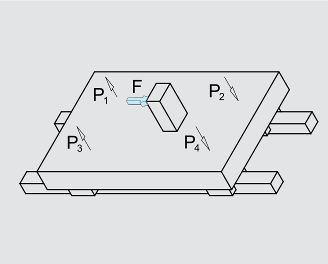
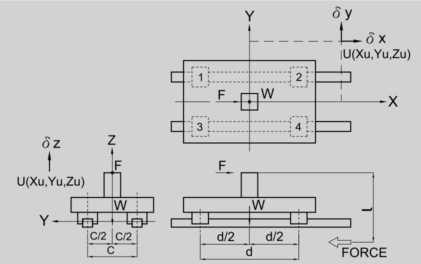
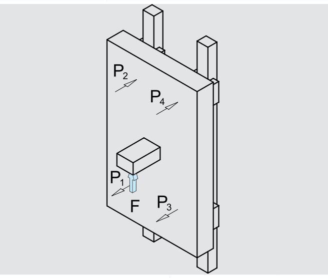
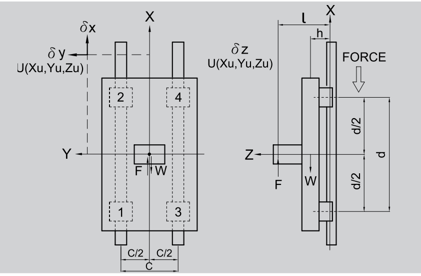
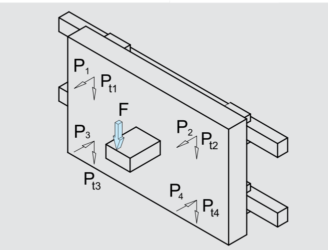
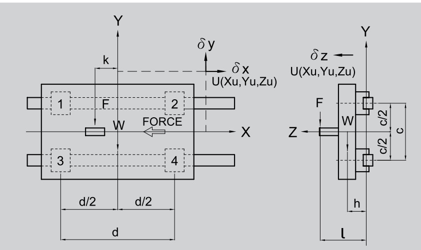
Several factors affect the calculation of loads acting on a linear guideway (such as the position of the object's center of gravity, the thrust position, and the inertial forces at the time of start and stop). To obtain the correct load value, each load condition should be carefully considered.

Linear Guideways

General Information

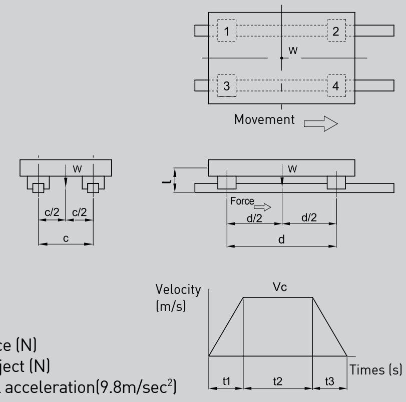
(1) Load on one block

Table 1.3 **Calculation example of loads on block**

Patterns	Loads layout	Load on the block and displacement of point U
		$P_1=\frac{W}{4}+\frac{F}{4}+\frac{F\cdot a}{2c}+\frac{F\cdot b}{2d}$ $P_2=\frac{W}{4}+\frac{F}{4}+\frac{F\cdot a}{2c}-\frac{F\cdot b}{2d}$ $P_3=\frac{W}{4}+\frac{F}{4}-\frac{F\cdot a}{2c}+\frac{F\cdot b}{2d}$ $P_4=\frac{W}{4}+\frac{F}{4}-\frac{F\cdot a}{2c}-\frac{F\cdot b}{2d}$ $\delta x=-Zu\cdot\frac{P_1-P_2}{d\cdot K}$, $\delta y=-Zu\cdot\frac{P_1-P_3}{c\cdot K}$ $\delta z=-\frac{F}{4\cdot K}+Xu\cdot\frac{P_1-P_2}{d\cdot K}-Yu\cdot\frac{P_1-P_3}{c\cdot K}$
		$P_1=\frac{W}{4}+\frac{F}{4}+\frac{F\cdot a}{2c}+\frac{F\cdot b}{2d}$ $P_2=\frac{W}{4}+\frac{F}{4}+\frac{F\cdot a}{2c}-\frac{F\cdot b}{2d}$ $P_3=\frac{W}{4}+\frac{F}{4}-\frac{F\cdot a}{2c}+\frac{F\cdot b}{2d}$ $P_4=\frac{W}{4}+\frac{F}{4}-\frac{F\cdot a}{2c}-\frac{F\cdot b}{2d}$ $\delta x=-Zu\cdot\frac{P_1-P_2}{d\cdot K}$, $\delta y=-Zu\cdot\frac{P_1-P_3}{c\cdot K}$ $\delta z=-\frac{F}{4\cdot K}+Xu\cdot\frac{P_1-P_2}{d\cdot K}-Yu\cdot\frac{P_1-P_3}{c\cdot K}$
		$P_1=P_3=\frac{W}{4}+\frac{F\cdot \ell}{2d}$ $P_2=P_4=\frac{W}{4}+\frac{F\cdot \ell}{2d}$ $\delta x=-Zu\cdot\frac{P_1+P_2}{d\cdot K}$ $\delta y=0$ $\delta z=-Xu\cdot\frac{P_1+P_2}{d\cdot K}$
		$P_1\sim P_4=-\frac{W\cdot h}{2d}+\frac{F\cdot \ell}{2d}$ $\delta x=-Zu\cdot\frac{P_1+P_2}{d\cdot K}$ $\delta y=0$ $\delta z=-Xu\cdot\frac{P_1+P_2}{d\cdot K}$
		$P_1\sim P_4=-\frac{W\cdot h}{2c}+\frac{F\cdot \ell}{2c}$ $P_{t1}=P_{t3}=\frac{W}{4}+\frac{F}{4}+\frac{F\cdot k}{2d}$ $P_{t2}=P_{t4}=\frac{W}{4}+\frac{F}{4}+\frac{F\cdot k}{2d}$ $\delta x=-Yu\cdot\frac{P_{t1}-P_{t2}}{d\cdot K}$ $\delta y=-\frac{F}{4\cdot K}+Xu\cdot\frac{P_{t1}-P_{t2}}{d\cdot K}-Zu\cdot\frac{P_1+P_3}{c\cdot K}$ $\delta z=-Yu\cdot\frac{P_1+P_3}{c\cdot K}$

(2) Loads with inertia forces

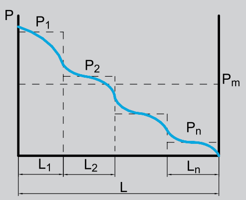
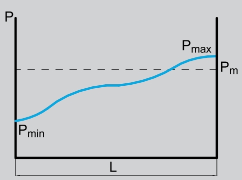
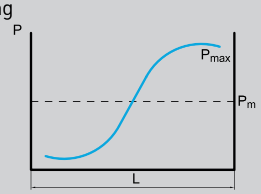
Table 1.4 **Calculation Examples for Loads with Inertia Forces**

Considering the acceleration and deceleration	Load on one block
 F : External force (N) W : Weight of object (N) g : Gravitational acceleration($9.8 m/sec^2$)	○ Constant velocity $P_1 \sim P_4 = \frac{W}{4}$ ○ Acceleration $P_1 = P_3 = \frac{W}{4} + \frac{1}{2} \cdot \frac{W}{g} \cdot \frac{V_c}{t1} \cdot \frac{l}{d}$ $P_2 = P_4 = \frac{W}{4} - \frac{1}{2} \cdot \frac{W}{g} \cdot \frac{V_c}{t1} \cdot \frac{l}{d}$ ○ Deceleration $P_1 = P_3 = \frac{W}{4} - \frac{1}{2} \cdot \frac{W}{g} \cdot \frac{V_c}{t3} \cdot \frac{l}{d}$ $P_2 = P_4 = \frac{W}{4} + \frac{1}{2} \cdot \frac{W}{g} \cdot \frac{V_c}{t3} \cdot \frac{l}{d}$

1-5-2 Calculation of The Mean Load for Variable Loading

When the load on a linear guideway fluctuates greatly, the variable load condition must be considered in the life calculation. The definition of the mean load is the load equal to the bearing fatigue load under the variable loading conditions. It can be calculated by using table 1.5.

Table 1.5 **Calculation Examples for Mean Load (P_m)**

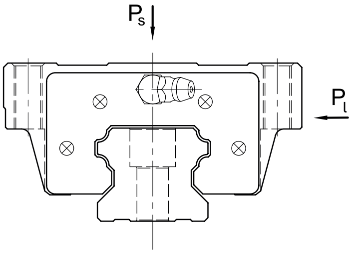
Operation Condition	Mean load
Step load 	$P_m = \sqrt[3]{1/L(P_1^3 \cdot L_1 + P_2^3 \cdot L_2 + \ldots + P_n^3 \cdot L_n)}$ P_m: Mean load P_n : Stepping L : Total running distance L_n : Running distance under load P_n
Linear variation 	$P_m = 1/3\,(P_{min} + 2 \cdot P_{max})$ P_m : Mean load P_{min} : Min. Load P_{max} : Max. Load
Sinusoidal loading 	$P_m = 0.65 \cdot P_{max}$ P_m : Mean load P_{max} : Max. Load

Linear Guideways

General Information

1-5-3 Calculation for Bidirectional Equivalent Loads

HIWIN linear guideways can accept loads in several directions simultaneously. To calculate the service life of the guideway when the loads appear in multiple directions, calculate the equivalent load (P_e) by using the equations below.



HG/EG Series

$$P_e = P_s + P_l \quad \text{Eq.1.5}$$

MG Series

when $P_s > P_l$ $\quad P_e = P_s + 0.5 \cdot P_l \quad$ Eq.1.6

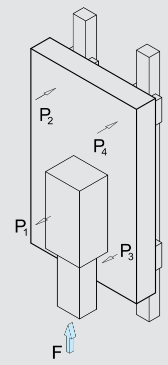
when $P_l > P_s$ $\quad P_e = P_l + 0.5 \cdot P_s \quad$ Eq.1.7

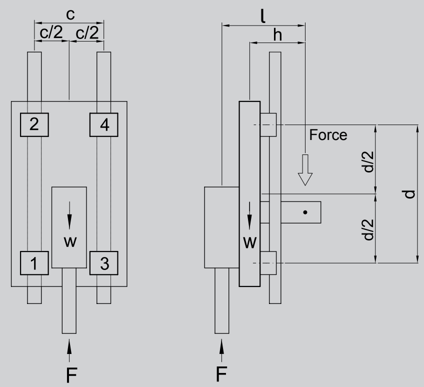
1-5-4 Calculation Example for Service Life

A suitable linear guideway should be selected based on the acting load. The service life is calculated from the ratio of the working load and the basic dynamic load rating.

Table 1.6 **Calculation Example for Service Life**

Type of Linear Guideway	Dimension of device	Operating condition
Type: HGH 30 CA	d : 600 mm	Weight (W) : 4 kN
C : 38.74 kN	c : 400 mm	Acting force (F) : 1 kN
C_0 : 83.06 kN	h : 200 mm	Temperature: normal temperature
Preload: ZA	l : 250 mm	Load status: normal load





- Calculation of acting loads

$$P_1 \sim P_4 = -\frac{W \cdot h}{2d} - \frac{F \cdot l}{2d} = \frac{4 \cdot 200}{2 \cdot 600} - \frac{1 \cdot 250}{2 \cdot 600} = 0.458(kN)$$

$$P_{max} = 0.458(kN)$$

- P_C is equal to the sum of P_{max} and preload

$$P_c = P_{max} + P_Z = 0.458 + (38.74 \cdot 0.07) = 3.17(kN)$$

- Calculation for life L

$$L = \left(\frac{f_h \cdot f_t \cdot C}{f_w \cdot P_c}\right)^3 \cdot 50 = \left(\frac{1 \cdot 1 \cdot 38.74}{2 \cdot 3.17}\right)^3 \cdot 50 = 11{,}400\ (km)$$

1-6 Lubrication

1-6-1 Grease

Each linear guideway is lubricated with lithium soap based grease before shipment. After the linear guideway is installed, we recommend that the guideway be re-lubricated every 100 km. It is possible to carry out the lubrication through the grease nipple. Generally, grease is applied for speeds that do not exceed 60 m/min faster speeds will require high-viscosity oil as a lubricant.

$$T = \frac{100 \cdot 1000}{V_e \cdot 60}\ hr \qquad \text{Eq.1.8}$$

T : Feeding frequency of oil (hour)
V_e : speed (m/min)

1-6-2 Oil

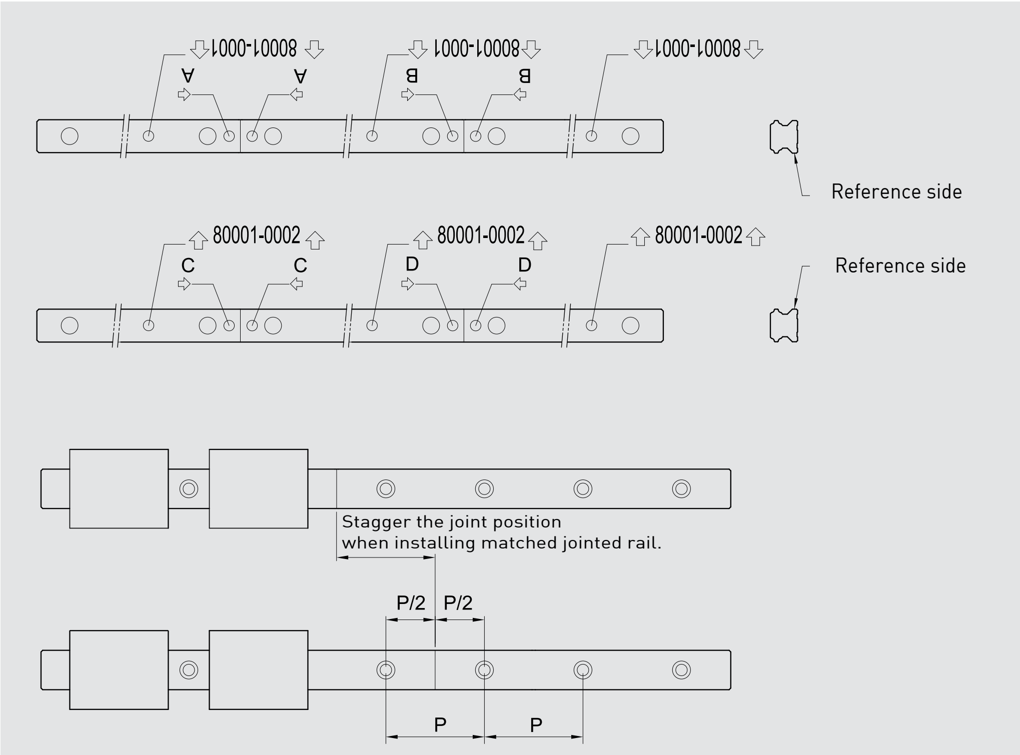
The recommended viscosity of oil is about 32~150cSt. The standard grease nipple may be replaced by an oil piping joint for oil lubrication. Since oil evaporates quicker than grease, the recommended oil feed rate is approximate 0.3cm^3/hr.

Linear Guideways

General Information

1-7 Jointed Rail

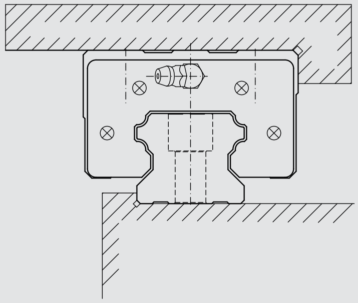
Jointed rail should be installed by following the arrow sign and ordinal number which is marked on the surface of each rail.
For matched pair, jointed rails, the jointed positions should be staggered. This will avoid accuracy problems due to discrepancies between the 2 rails (see figure).



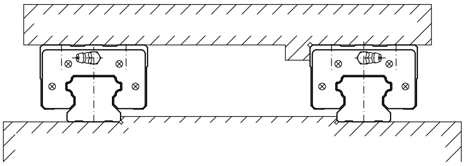
1-8 Mounting Configurations

Linear guideways have equal load ratings in the radial, reverse radial and lateral directions.
The application depends on the machine requirements and load directions.
Typical layouts for linear guideways are shown below:

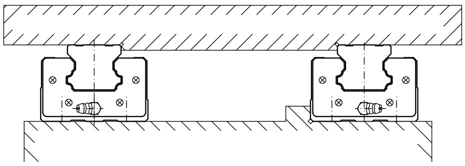
Use of one rail and mounting reference side



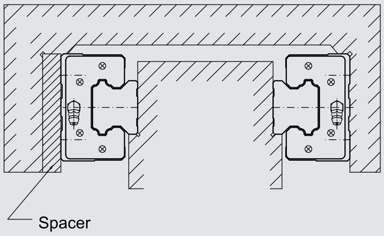
use of two rails(block movement)



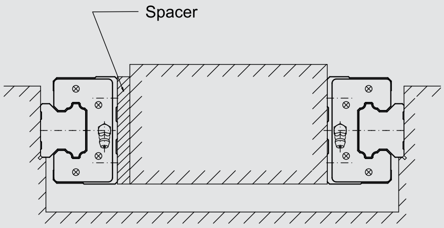
use of two rails(block fixed)



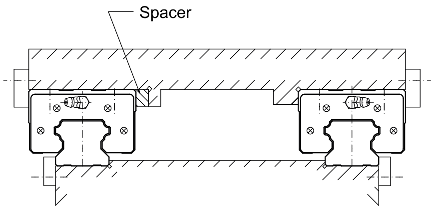
use of two external rails



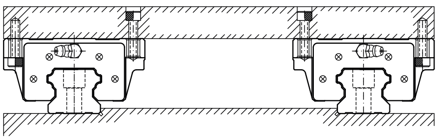
use of two internal rails



total surface fixed installation



HGW type block with mounting holes in different directions.



Linear Guideways

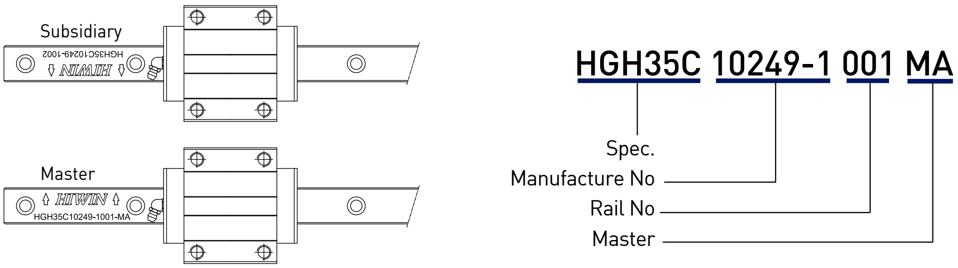
General Information

1-9 Mounting Procedures

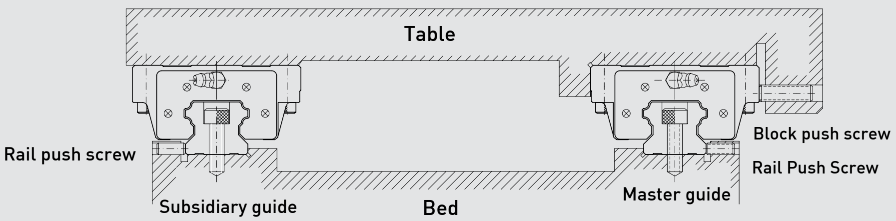
Three installation methods are recommended based on the required running accuracy and the degree of impacts and vibrations.

1-9-1 Master and Subsidiary Guide

For non-interchangeable type Linear Guideways, there are some differences between the master guide and subsidiary guide. The accuracy of the master guide's datum plane is better than the subsidiary's and it can be a reference side for installation. There is a mark "MA" printed on the rail, as shown in the figure below.



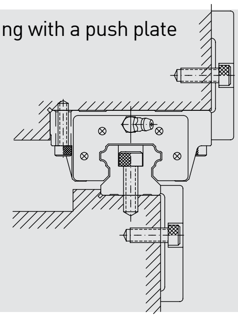
1-9-2 Installation to Achieve High Accuracy and Rigidity



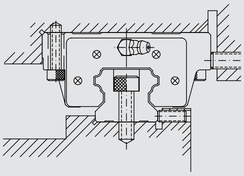
(1) Mounting methods

It is possible that the rails and the blocks will be displaced when the machine is subjected to vibrations and impacts. To eliminate these difficulties and achieve high running accuracy, the following four methods are recommended for fixing.

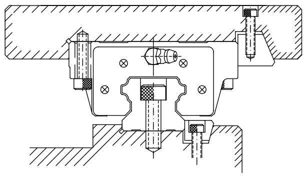
Mounting with a push plate



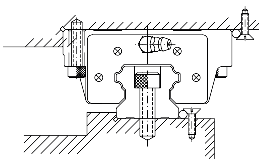
Mounting with push screws



Mounting with taper gib

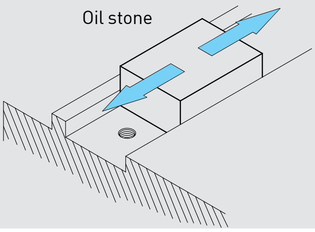


Mounting with needle roller

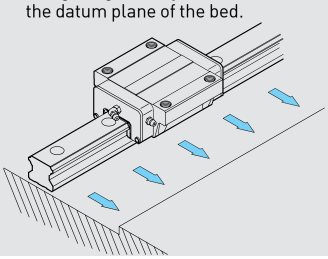


(2) Procedure of rail installation

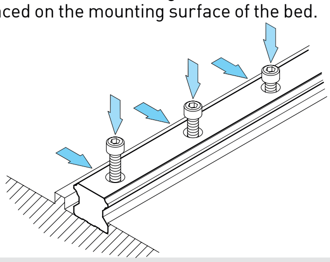
1 Before starting, remove all dirt from the mounting surface of the machine.



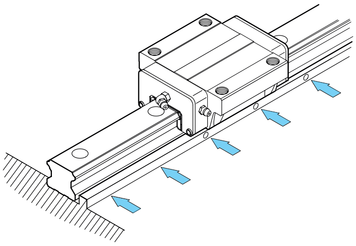
2 Place the linear guideway gently on the bed. Bring the guideway into close contact with the datum plane of the bed.



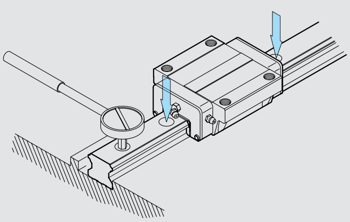
3 Check for correct thread engagement when inserting a bolt into the mounting hole while the rail is being placed on the mounting surface of the bed.



4 Tighten the push screws sequentially to ensure close contact between the rail and the side datum plane.



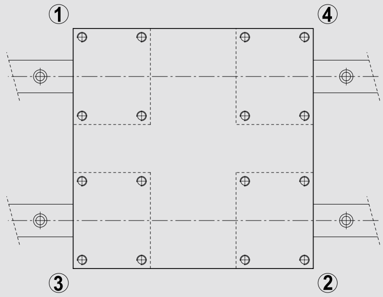
5 Tighten the mounting bolts with a torque wrench to the specified torque.



6 Install the remaining linear guideway in the same way.

Linear Guideways
General Information

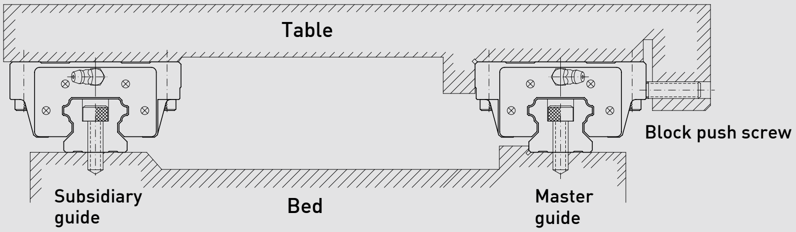
(3) Procedure of block installation



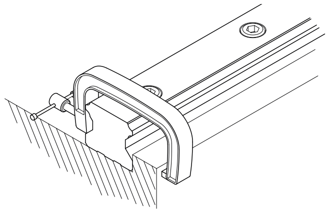
- Place the table gently on the blocks. Next, tighten the block mounting bolts temporarily.
- Push the blocks against the datum plane of the table and position the table by tightening the push screws.
- The table can be fixed uniformly by tightening the mounting bolts on master guide side and subsidiary side in 1 to 4 sequences.

1-9-3 Installation of the Master Guide without Push Screws

To ensure parallelism between the subsidiary guide and the master guide without push screws, the following rail installation methods are recommended. The block installation is the same as mentioned previously.

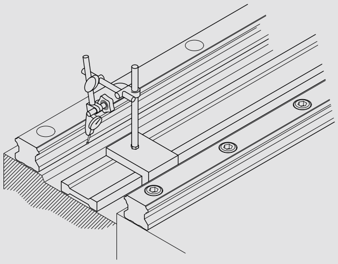


(1) Installation of the rail on the subsidiary guide side

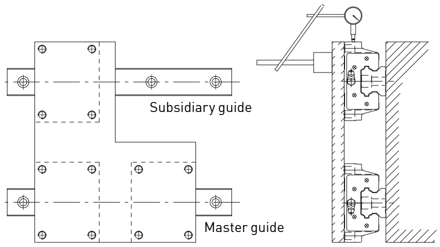


- **Using a vice**
  Place the rail into the mounting plane of the bed. Tighten the mounting bolts temporarily; then use a vice to push the rail against the side datum plane of the bed. Tighten the mounting bolts in sequence to the specified torque.

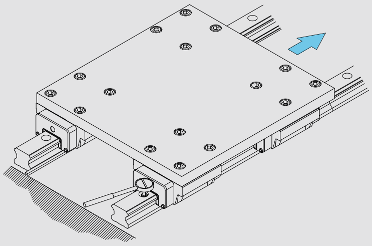
(2) Installation of the rail on the subsidiary guide side



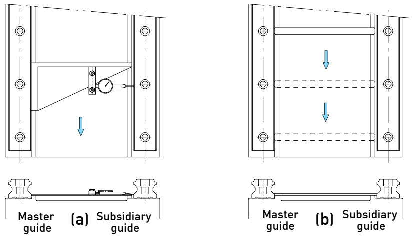
Method with use of a straight edge
Set a straight edge between the rails parallel to the side datum plane of the rail on the master guide side by using a dial gauge. Use the dial gauge to obtain the straight alignment of the rail on the subsidiary guide side. When the rail on the subsidiary guide side is parallel to the master side, tighten the mounting bolts in sequence from one end of the rail to the other.



Method with use of a table
Fix two blocks on the master guide side to the table. Temporarily fix the rail and one block on the subsidiary guide side to the bed and the table. Fix a dial gauge stand on the table surface and bring it into contact with the side of the block on the subsidiary guide side. Move the table from one end of the rail to the other. While aligning the rail on the subsidiary side parallel to the rail on the master guide side, tighten the bolts in sequence.



Method following the master guide side
When a rail on the master guide side is correctly tightened, fix both blocks on the master guide side and one of the two blocks on the subsidiary guide side completely to the table.
When moving the table from one end of the rail, tighten the mounting bolts on the subsidiary guide side completely.



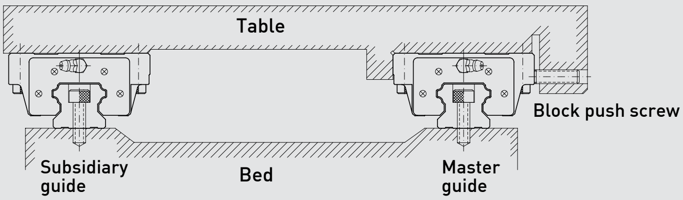
Method with use of a jig
Use a special jig to ensure the rail position on the subsidiary guide side. Tighten the mounting bolts to the specified torque in sequence.

Linear Guideways

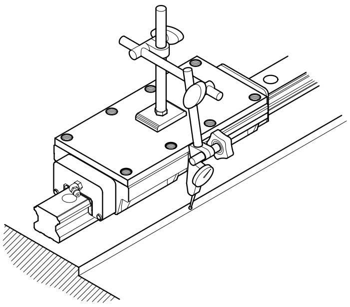
General Information

1-9-4 When There Is No Side Surface of The Bed On The Master Guide Side

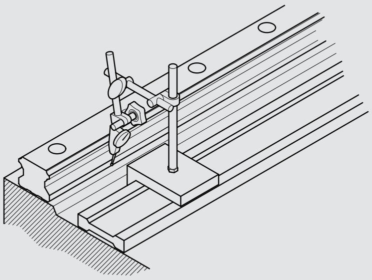
To ensure parallelism between the subsidiary guide and the master guide when there is no side surface, the following rail installation method is recommended. The installation of the blocks is the same as mentioned previously.



(1) Installation of the rail on the master guide side



- **Using a provisional datum plane**
  Two blocks are fixed in close contact by the measuring plate. A datum plane provided on the bed is used for straight alignment of the rail from one end to the other. Move the blocks and tighten the mounting bolts to the specified torque in sequence.



- **Method with use of a straight edge**
  Use a dial gauge and a straight edge to confirm the straightness of the side datum plane of the rail from one end to the other. Make sure the mounting bolts are tightened securely in sequence.

(2) Installation of the rail on the subsidiary guide side

The method of installation for the rail on the subsidiary guide side is the same as the case without push screws.