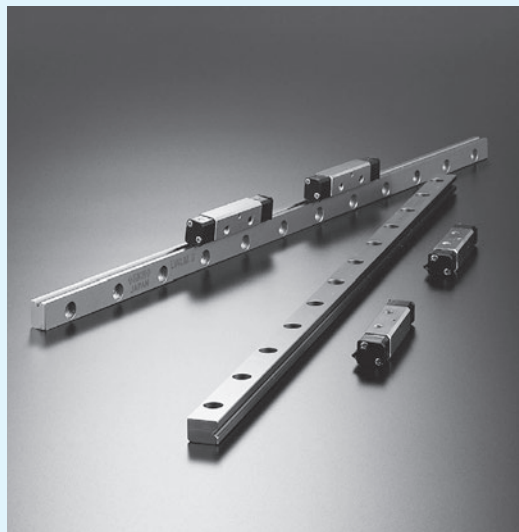


General Explanation



Selection Procedure

Selection of Linear Way and Linear Roller Way should be considered from the most important required matter to details in order.
Typical procedure is shown below.

Example of Linear Way and Linear Roller Way selection procedure



Life of linear motion rolling guides

Even in normal operational status, a linear motion rolling guide will reach the end of its life after a certain period of operations. As repeated load is constantly applied onto a raceway and rolling elements of the linear motion rolling guide, this leads to leprous damage (scale-like wear fragments) called fatigue flaking due to rolling contact fatigue of materials, it will be unusable at the end. Total traveling distance before occurrence of this fatigue flaking on a raceway or rolling elements is called the life of linear motion rolling guide.

As the life of linear motion rolling guide may vary depending on material fatigue phenomenon, rating life based on statistic calculation is used.

Rating life

Rating life of linear motion rolling guide refers to the total traveling distance 90% of a group of the same linear motion rolling guide can operate without linear motion rolling guide material damages due to rolling contact fatigue when they are operated individually under the same conditions.

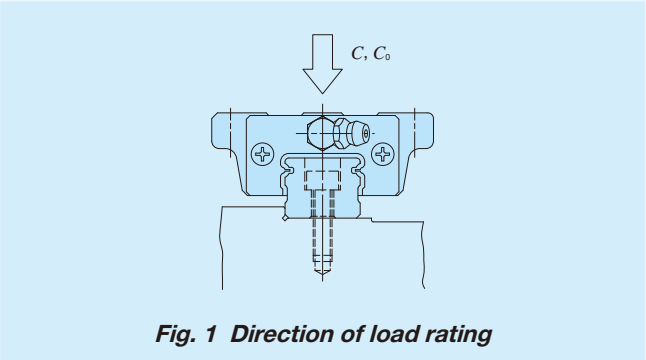


Fig. 1 Direction of load rating

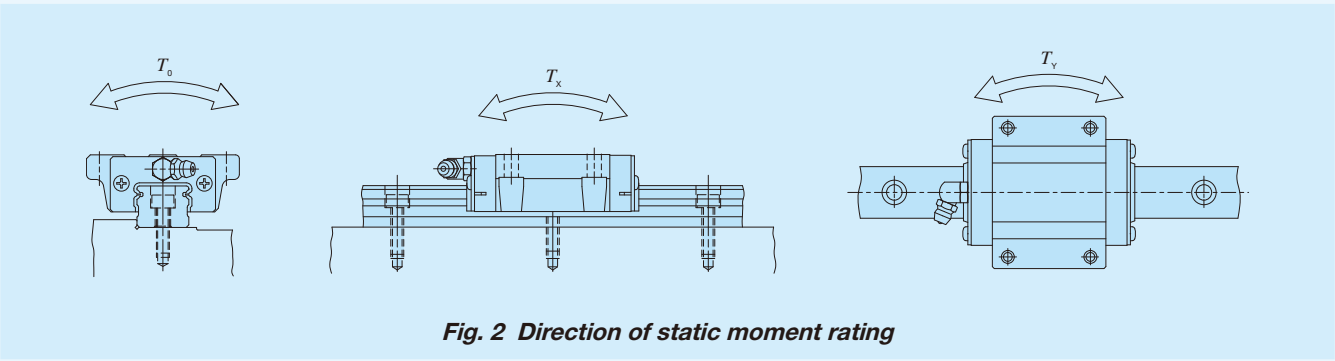


Fig. 2 Direction of static moment rating

Basic dynamic load rating C

Complying with ISO 14728-1

Basic dynamic load rating refers to load with certain direction and size that is logically endurable for rating life of 50×10³ m when a group of the same linear motion rolling guides is operated individually under the same conditions.

Basic static load rating C0

Complying with ISO 14728-2

Basic static load rating refers to static load generating a certain contact stress at the center of contact part of the rolling elements and a raceway under maximum load, which is the load at the allowable limit for normal rolling motion. Generally, it is used considering static safety factor.

Static moment rating T0, Tx, Ty

Static moment rating refers to static moment load generating a certain contact stress at the center of contact parts of rolling elements and a raceway under the maximum load when the moment load shown in Fig. 2 is loaded, which is the moment load at the allowable limit for normal rolling motion. Generally, it is used considering static safety factor.

Calculating formula of life

The rating life calculation formulas are shown below.

Linear Way
$$L=50\left(\frac{C}{P}\right)^3 \cdots \cdots \cdots (1)$$

Linear Roller Way
$$L=50\left(\frac{C}{P}\right)^{10/3} \cdots \cdots \cdots (2)$$

where, L: Rating life, 10³ m
C: Basic dynamic load rating, N
P: Dynamic equivalent load, N

Life time can be calculated by applying a stroke length and a number of strokes per minute to the formula below.

$$L_h=\frac{10^6 L}{2Sn_1 \times 60} \cdots \cdots \cdots (3)$$

where, L_h: Rating life in hours, h
S: Stroke length, mm
n₁: Number of strokes per minute, cpm

Load factor

Load applied to a linear motion rolling guide can be larger than theoretical load due to machine vibration or shock. Generally, the applied load is obtained by multiplying it by the load factor indicated in Table 1.

Table 1 Load factor

Operating conditions	f _w
Smooth operation free from shock	1 ~ 1.2
Normal operation	1.2 ~ 1.5
Operation with shock load	1.5 ~ 3

Static safety factor

Generally, basic static load rating and static moment rating is considered as load at the allowable limit for normal rolling motion. However, static safety factor must be considered according to operating conditions and required performance of the linear motion rolling guide.

Static safety factor can be obtained by the following equation and typical values are indicated in Tables 2.1 and 2.2.

Equation (5) is a representative equation for a moment load. Moment load and static moment rating in each direction is applied for the calculation.

$$f_s=\frac{C_0}{P_0} \cdots \cdots \cdots (4)$$

$$f_s=\frac{T_0}{M_0} \cdots \cdots \cdots (5)$$

where, f_s: Static safety factor
C₀: Basic static load rating, N
P₀: Static equivalent load, N
T₀: Static moment rating, N · m
M₀: Moment load in each direction, N · m (maximum moment load)

Table 2.1 Static safety factor for Linear Way

Operational conditions	f _s
Operation with vibration and / or shock	3 ~ 5
High operating performance	2 ~ 4
Normal operating conditions	1 ~ 3

Table 2.2 Static safety factor for Linear Roller Way

Operational conditions	f _s
Operation with vibration and / or shock	4 ~ 6
High operating performance	3 ~ 5
Normal operating conditions	2.5 ~ 3

Dynamic equivalent load

When a load is applied in a direction other than that of the basic dynamic load rating or a complex load is applied, the dynamic equivalent load must be calculated to obtain the basic rating life.

Obtain the downward and lateral conversion loads from the loads and moments in various directions.

$$F_{re}=k_r|F_r|+\frac{C_0}{T_0}|M_0|+\frac{C_0}{T_x}|M_x| \dots\dots\dots (6)$$

$$F_{ae}=k_a|F_a|+\frac{C_0}{T_y}|M_y| \dots\dots\dots (7)$$

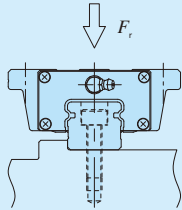
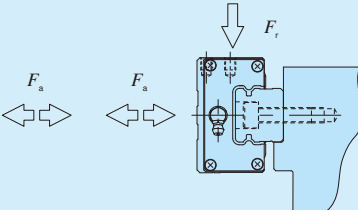
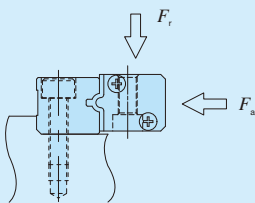
[For Linear Way H Side mounting type (LWHY)]

$$F_{ae}=k_a|F_a|+\frac{C_0}{T_0}|M_0|+\frac{C_0}{T_x}|M_x| \dots\dots\dots (8)$$

$$F_{re}=k_r|F_r|+\frac{C_0}{T_y}|M_y| \dots\dots\dots (9)$$

where, F_{re} : Downward conversion load, N
 F_{ae} : Lateral conversion load, N
 F_r : Downward load, N
 F_a : Lateral load, N
 M_0 : Moment load in the T_0 direction, N · m
 M_x : Moment load in the T_x direction, N · m
 M_y : Moment load in the T_y direction, N · m
 k_r, k_a : Conversion factors for load direction (See Table 3)
 C_0 : Basic static load rating, N
 T_0 : Static moment rating in the T_0 direction, N · m
 T_x : Static moment rating in the T_x direction, N · m
 T_y : Static moment rating in the T_y direction, N · m

Table 3 Conversion factor for load direction

			
Linear Way and Linear Roller Way		Linear Way H Side mounting type	
			
Linear Way Module			

Series name and size		Conversion factor			
		k_r		k_a	
		$F_r \geq 0$	$F_r < 0$		
C-Lube Linear Way ML	Ball retained type	1	1	1.19	
Linear Way L	Ball non-retained type	1	1	0.84	
C-Lube Linear Way MLV		1	1	1.19	
C-Lube Linear Way MV		1	1.23	1.35	
C-Lube Linear Way ME	15~30	1	1	1	
Linear Way E	35~45	1	1.19	1.28	
Low Decibel Linear Way E		1	1	1	
C-Lube Linear Way MH	8~12	1	1	1.19	
	15~30	1	1	1	
	35~65	1	1.19	1.28	
	Linear Way H	15~30	1	1	1
	Horizontal mounting type	35~45 ⁽¹⁾	1	1	0.84 0.95
Linear Way F	33~42	1	1	1	
	69	1	1	1.19	
	LWFH	1	1.19	1.28	
C-Lube Linear Way MUL	25, 30	1	1	1.19	
Linear Way U	40~86	1	1	1	
C-Lube Linear Roller Way Super MX		1	1	1	
Linear Roller Way Super X		1	1	1	
Linear Way Module	LWLM	1	1	0.73	
	LWM	1~5	1	1.13	0.73
		6	1	1.28	0.76
	LRWM		1	1	0.58

Note ⁽¹⁾ The upper value of k_a columns represents the right direction and the lower value represents the left direction.

Obtain the dynamic equivalent load from the downward and lateral conversion loads.

$$P=XF_{re}+YF_{ae} \dots\dots\dots (10)$$

where, P : Dynamic equivalent load, N
 X, Y : Dynamic equivalent load factor (See Table 4)
 F_{re} : Downward conversion load, N
 F_{ae} : Lateral conversion load, N

Table 4 Dynamic equivalent load factor

Class	X	Y
$ F_{re} \geq F_{ae} $	1	0.6
$ F_{re} < F_{ae} $	0.6	1

Static equivalent load

When a load is applied in a direction other than that of the basic static load rating or a complex load is applied, the static equivalent load must be calculated to obtain the static safety factor.

$$P_0=k_{or}|F_r|+k_{oa}|F_a|+\frac{C_0}{T_0}|M_0|+\frac{C_0}{T_x}|M_x|+\frac{C_0}{T_y}|M_y| \dots\dots (11)$$

where, P_0 : Static equivalent load, N
 F_r : Downward load, N
 F_a : Lateral load, N
 M_0 : Moment load in the T_0 direction, N · m
 M_x : Moment load in the T_x direction, N · m
 M_y : Moment load in the T_y direction, N · m
 k_{or}, k_{oa} : Conversion factors for load direction (See Table 5)
 C_0 : Basic static load rating, N
 T_0 : Static moment rating in the T_0 direction, N · m
 T_x : Static moment rating in the T_x direction, N · m
 T_y : Static moment rating in the T_y direction, N · m

Table 5 Conversion factor for load direction

Linear Way and Linear Roller Way

Linear Way H Side mounting type

Linear Way Module

Series name and size		Conversion factor		
		k_{or}	k_{oa}	
		$F_r \geq 0$	$F_r < 0$	
C-Lube Linear Way ML	Ball retained type	1	1	1.19
Linear Way L	Ball non-retained type	1	1	0.84
C-Lube Linear Way MLV		1	1	1.19
C-Lube Linear Way MV		1	1.88	2.08
C-Lube Linear Way ME	15~30	1	1	1
Linear Way E	35~45	1	1.19	1.28
Low Decibel Linear Way E		1	1	1
C-Lube Linear Way MH		1	1	1.19
Linear Way H		1	1	1
Linear Way H Horizontal mounting type	15~30	1	1	1
	35~45 ⁽¹⁾	1	1	0.78
				0.93
Linear Way F	33~42	1	1	1
	69	1	1	1.19
	LWFH	1	1.19	1.28
C-Lube Linear Way MUL	25, 30	1	1	1.19
Linear Way U	40~86	1	1	1
C-Lube Linear Roller Way Super MX		1	1	1
Linear Roller Way Super X		1	1	1
Linear Way Module	LWLM	1	1	0.60
	LWM	1~5	1	1.19
	6	1	1.43	0.67
	LRWM	1	1	0.50

Note ⁽¹⁾ The upper value of k_{oa} columns represents the right direction and the lower value represents the left direction.

Calculated Load

Examples of calculation for the loads applied to Linear Way and Linear Roller Way that is incorporated in machine / equipment is shown in Table 6.1 to Table 6.6.

Table 6.1 One track rail and one slide unit

Slide unit No.	Load applied on the slide unit				
	Downward load F_r	Lateral load F_a	Moment load in the T_0 direction M_0	Moment load in the T_x direction M_x	Moment load in the T_y direction M_y
1	F_z	F_y	M_r	M_p	M_y

Remark: The moment loads in each direction M_r , M_p , M_y can be obtained by the following equation.

$M_r = F_y Z + F_z Y$
 $M_p = F_x (Z - Z_d) + F_z X$
 $M_y = -F_x (Y - Y_d) + F_y X$

Table 6.2 One track rail and two slide units

Slide unit No.	Load applied on the slide unit		
	Downward load F_r	Lateral load F_a	Moment load in the T_0 direction M_0
1	$\frac{F_z}{2} + \frac{M_p}{l}$	$\frac{F_y}{2} + \frac{M_r}{l}$	$\frac{M_r}{2}$
2	$\frac{F_z}{2} - \frac{M_p}{l}$	$\frac{F_y}{2} - \frac{M_r}{l}$	$\frac{M_r}{2}$

Remark: The moment loads in each direction M_r , M_p , M_y can be obtained by the following equation.

$M_r = F_y Z + F_z Y$
 $M_p = F_x (Z - Z_d) + F_z X$
 $M_y = -F_x (Y - Y_d) + F_y X$

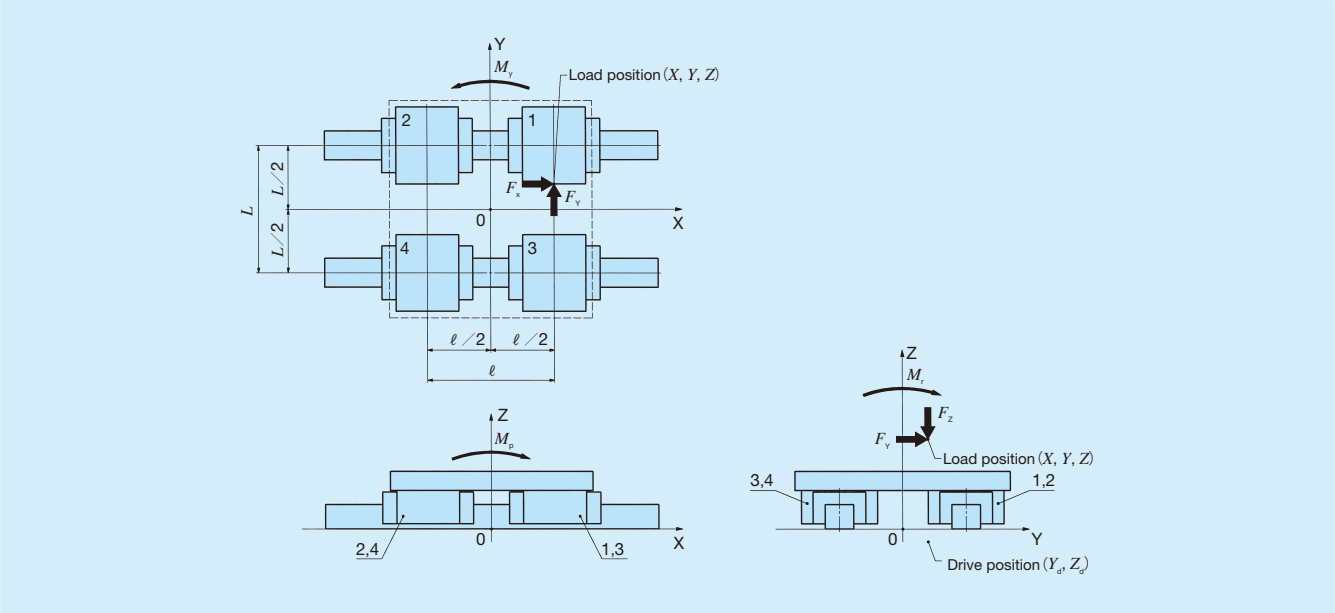
Table 6.3 Two track rails and one slide unit

Slide unit No.	Load applied on the slide unit			
	Downward load F_r	Lateral load F_a	Moment load in the T_x direction M_x	Moment load in the T_y direction M_y
1	$\frac{F_z}{2} + \frac{M_r}{L}$	$\frac{F_y}{2}$	$\frac{M_p}{2}$	$\frac{M_y}{2}$
2	$\frac{F_z}{2} - \frac{M_r}{L}$	$\frac{F_y}{2}$	$\frac{M_p}{2}$	$\frac{M_y}{2}$

Remark: The moment loads in each direction M_r , M_p , M_y can be obtained by the following equation.

$M_r = F_y Z + F_z Y$
 $M_p = F_x (Z - Z_d) + F_z X$
 $M_y = -F_x (Y - Y_d) + F_y X$

Table 6.4 Two track rails and two slide units

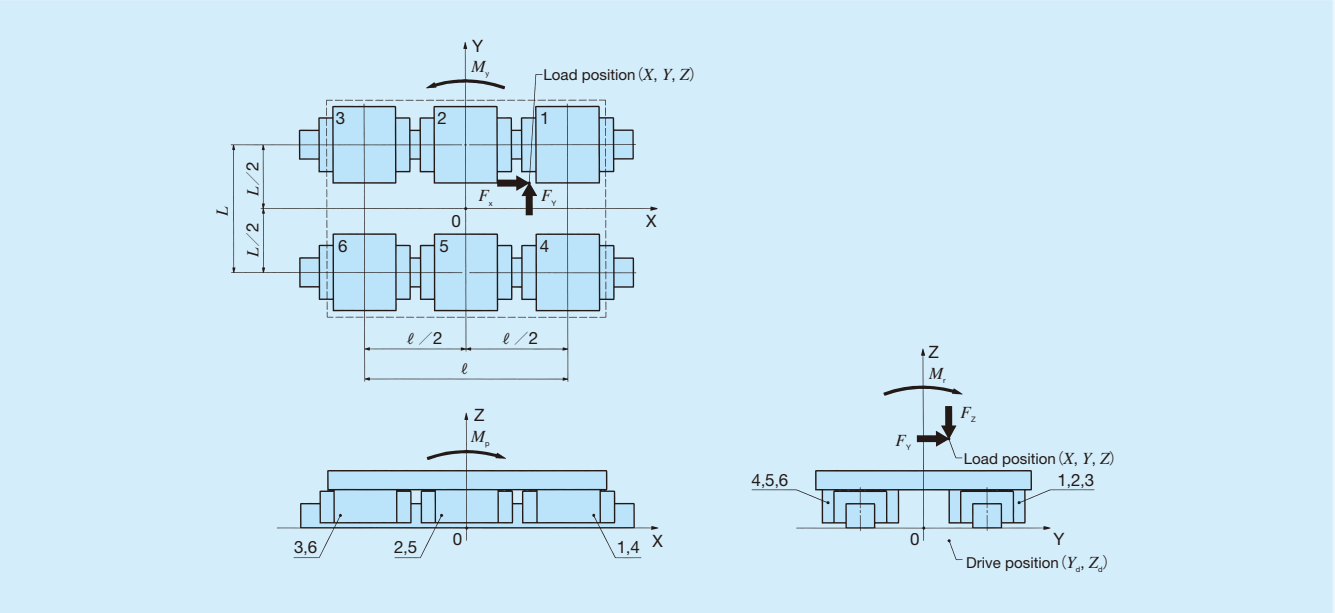


Slide unit No.	Load applied on the slide unit	
	Downward load F_r	Lateral load F_a
1	$\frac{F_z}{4} + \frac{M_r}{2L} + \frac{M_p}{2l}$	$\frac{F_y}{4} + \frac{M_y}{2l}$
2	$\frac{F_z}{4} + \frac{M_r}{2L} - \frac{M_p}{2l}$	$\frac{F_y}{4} - \frac{M_y}{2l}$
3	$\frac{F_z}{4} - \frac{M_r}{2L} + \frac{M_p}{2l}$	$\frac{F_y}{4} + \frac{M_y}{2l}$
4	$\frac{F_z}{4} - \frac{M_r}{2L} - \frac{M_p}{2l}$	$\frac{F_y}{4} - \frac{M_y}{2l}$

Remark: The moment loads in each direction M_r , M_p , M_y can be obtained by the following equation.

$$M_r = F_y Z + F_z Y$$
$$M_p = F_x (Z - Z_d) + F_z X$$
$$M_y = -F_x (Y - Y_d) + F_y X$$

Table 6.5 Two track rails and three slide units

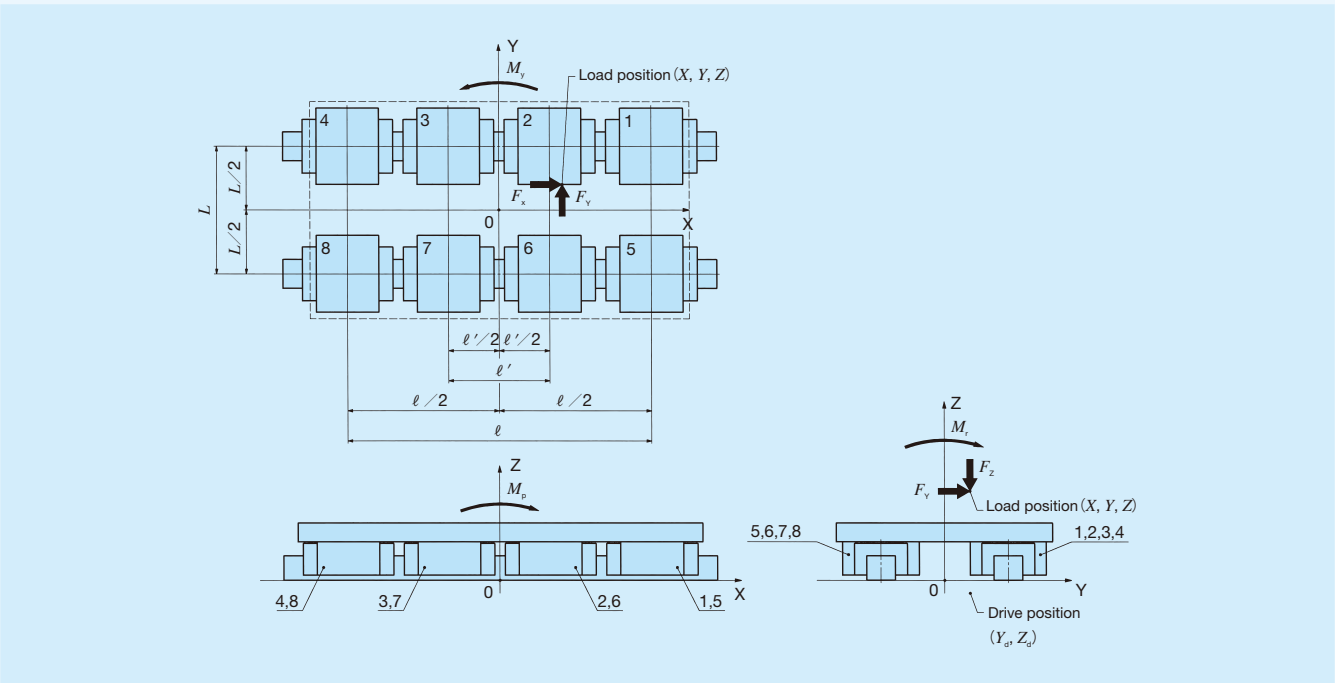


Slide unit No.	Load applied on the slide unit	
	Downward load F_r	Lateral load F_a
1	$\frac{F_z}{6} + \frac{M_r}{3L} + \frac{M_p}{2l}$	$\frac{F_y}{6} + \frac{M_y}{2l}$
2	$\frac{F_z}{6} + \frac{M_r}{3L}$	$\frac{F_y}{6}$
3	$\frac{F_z}{6} + \frac{M_r}{3L} - \frac{M_p}{2l}$	$\frac{F_y}{6} - \frac{M_y}{2l}$
4	$\frac{F_z}{6} - \frac{M_r}{3L} + \frac{M_p}{2l}$	$\frac{F_y}{6} + \frac{M_y}{2l}$
5	$\frac{F_z}{6} - \frac{M_r}{3L}$	$\frac{F_y}{6}$
6	$\frac{F_z}{6} - \frac{M_r}{3L} - \frac{M_p}{2l}$	$\frac{F_y}{6} - \frac{M_y}{2l}$

Remark: The moment loads in each direction M_r , M_p , M_y can be obtained by the following equation.

$$M_r = F_y Z + F_z Y$$
$$M_p = F_x (Z - Z_d) + F_z X$$
$$M_y = -F_x (Y - Y_d) + F_y X$$

Table 6.6 Two track rails and four slide units



Slide unit No.	Load applied on the slide unit	
	Downward load F_r	Lateral load F_a
1	$\frac{F_z}{8} + \frac{M_r}{4L} + \frac{M_p}{2} \frac{\ell}{\ell^2 + \ell'^2}$	$\frac{F_y}{8} + \frac{M_y}{2} \frac{\ell}{\ell^2 + \ell'^2}$
2	$\frac{F_z}{8} + \frac{M_r}{4L} + \frac{M_p}{2} \frac{\ell'}{\ell^2 + \ell'^2}$	$\frac{F_y}{8} + \frac{M_y}{2} \frac{\ell'}{\ell^2 + \ell'^2}$
3	$\frac{F_z}{8} + \frac{M_r}{4L} - \frac{M_p}{2} \frac{\ell'}{\ell^2 + \ell'^2}$	$\frac{F_y}{8} - \frac{M_y}{2} \frac{\ell'}{\ell^2 + \ell'^2}$
4	$\frac{F_z}{8} + \frac{M_r}{4L} - \frac{M_p}{2} \frac{\ell}{\ell^2 + \ell'^2}$	$\frac{F_y}{8} - \frac{M_y}{2} \frac{\ell}{\ell^2 + \ell'^2}$
5	$\frac{F_z}{8} - \frac{M_r}{4L} + \frac{M_p}{2} \frac{\ell}{\ell^2 + \ell'^2}$	$\frac{F_y}{8} + \frac{M_y}{2} \frac{\ell}{\ell^2 + \ell'^2}$
6	$\frac{F_z}{8} - \frac{M_r}{4L} + \frac{M_p}{2} \frac{\ell'}{\ell^2 + \ell'^2}$	$\frac{F_y}{8} + \frac{M_y}{2} \frac{\ell'}{\ell^2 + \ell'^2}$
7	$\frac{F_z}{8} - \frac{M_r}{4L} - \frac{M_p}{2} \frac{\ell'}{\ell^2 + \ell'^2}$	$\frac{F_y}{8} - \frac{M_y}{2} \frac{\ell'}{\ell^2 + \ell'^2}$
8	$\frac{F_z}{8} - \frac{M_r}{4L} - \frac{M_p}{2} \frac{\ell}{\ell^2 + \ell'^2}$	$\frac{F_y}{8} - \frac{M_y}{2} \frac{\ell}{\ell^2 + \ell'^2}$

Remark: The moment loads in each direction M_r , M_p , M_y can be obtained by the following equation.

$M_r = F_y Z + F_z Y$
 $M_p = F_x (Z - Z_d) + F_z X$
 $M_y = -F_x (Y - Y_d) + F_y X$

Mean Equivalent Load for Fluctuating Load

When the load on the Linear Way and Linear Roller Way varies, instead of dynamic equivalent load P , the mean equivalent load P_m is used for calculating formula of life. The mean equivalent load is a load converted to give life equal to that for fluctuating load. It is obtained by the following formula:

$$P_m = \sqrt[p]{\frac{1}{L} \int_0^L P_n^p dL} \dots\dots\dots (12)$$

- where, P_m : Mean equivalent load, N
- L : Total traveling distance, m
- P_n : Fluctuating load, N
- p : Exponent (ball type: 3, roller type: 10/3)

Table 7 gives calculation examples of the mean equivalent load for typical fluctuating loads.

Table 7 Mean equivalent load for fluctuating load

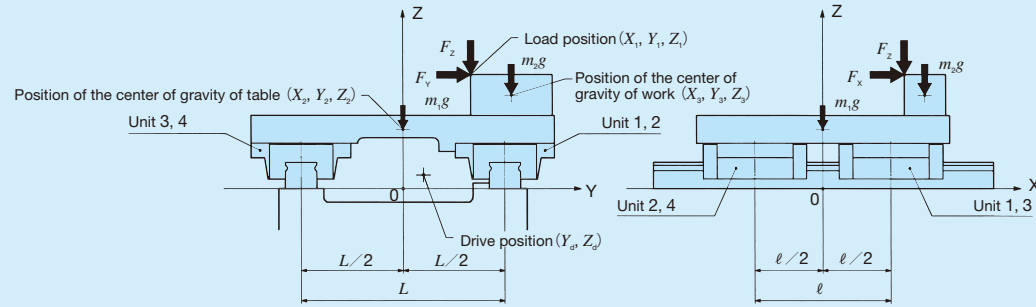
Example		Mean equivalent load
① Stepwise changing load		$P_m = \sqrt[p]{\frac{1}{L} (P_1^p L_1 + P_2^p L_2 + \dots + P_n^p L_n)}$ where, L_1 : Total traveling distance receiving the load P_1, m L_2 : Total traveling distance receiving the load P_2, m L_n : Total traveling distance receiving the load P_n, m
② Monotonously changing load		$P_m \doteq \frac{1}{3} (2P_{max} + P_{min})$ where, P_{max} : Maximum value of fluctuating load, N P_{min} : Minimum value of fluctuating load, N

Examples of Load and Life Calculation

Example 1

Linear Way Model.....ME 25 C2 R640 H
Basic dynamic load rating..... $C = 18100 \text{ N}$
Basic static load rating..... $C_0 = 21100 \text{ N}$
Applied load..... $F_{x1} = 1000 \text{ N}$
..... $F_{y1} = 2000 \text{ N}$
..... $F_{z1} = 1000 \text{ N}$
Load position..... $X_1 = 60 \text{ mm}$
..... $Y_1 = 50 \text{ mm}$
..... $Z_1 = 83 \text{ mm}$
Table mass..... $m_1 = 10 \text{ kg}$
Position of the center of gravity of table..... $X_2 = 0 \text{ mm}$
..... $Y_2 = 0 \text{ mm}$
..... $Z_2 = 43 \text{ mm}$

Work mass..... $m_2 = 10 \text{ kg}$
Position of center of gravity of work..... $X_3 = 75 \text{ mm}$
..... $Y_3 = 80 \text{ mm}$
..... $Z_3 = 68 \text{ mm}$
Number of strokes per minute..... $n_1 = 5 \text{ cpm}$
Stroke length..... $S = 100 \text{ mm}$
Distance between slide units..... $\ell = 100 \text{ mm}$
Distance between the track rails..... $L = 150 \text{ mm}$
Drive position..... $Y_d = 150 \text{ mm}$
..... $Z_d = 10 \text{ mm}$



The life and static safety factor in the case of Example 1 is calculated. Load factor f_w is assumed to be 1.5.

① Calculation of load on the slide unit

Due to the applied load and the table weight, moment load occurs around each coordinate axis of the Linear Way as shown below.

$$\begin{aligned} M_r &= \Sigma (F_y Z) + \Sigma (F_z Y) = F_{y1} Z_1 + F_{z1} Y_1 + m_1 g Y_2 + m_2 g Y_3 \\ &= 2000 \times 83 + 1000 \times 50 + 10 \times 9.8 \times 0 + 10 \times 9.8 \times 80 \\ &\approx 224000 \\ M_p &= \Sigma \{F_x (Z - Z_d)\} + \Sigma (F_z X) = F_{x1} (Z_1 - Z_d) + F_{z1} X_1 + m_1 g X_2 \\ &\quad + m_2 g X_3 \\ &= 1000 \times (83 - 10) + 1000 \times 60 + 10 \times 9.8 \times 0 + 10 \times 9.8 \\ &\quad \times 75 \approx 140000 \\ M_y &= -\Sigma \{F_x (Y - Y_d)\} + \Sigma (F_y X) = -F_{x1} (Y_1 - Y_d) + F_{y1} X_1 \\ &= -1000 \times (50 - 150) + 2000 \times 60 = 220000 \end{aligned}$$

where, M_r : Moment load in the rolling direction, N · mm
 M_p : Moment load in the pitching direction, N · mm
 M_y : Moment load in the yawing direction, N · mm

The loads applied on each slide unit are calculated according to Table 6.4 on page III - 11.

$$\begin{aligned} F_{r1} &= \frac{\Sigma F_z}{4} + \frac{M_r}{2L} + \frac{M_p}{2\ell} = \frac{F_{z1} + m_1 g + m_2 g}{4} + \frac{M_r}{2L} + \frac{M_p}{2\ell} \\ &= \frac{1000 + 10 \times 9.8 + 10 \times 9.8}{4} + \frac{224000}{2 \times 150} + \frac{140000}{2 \times 100} \\ &\approx 1750 \\ F_{r2} &= \frac{\Sigma F_z}{4} + \frac{M_r}{2L} - \frac{M_p}{2\ell} = \frac{F_{z1} + m_1 g + m_2 g}{4} + \frac{M_r}{2L} - \frac{M_p}{2\ell} \approx 346 \\ F_{r3} &= \frac{\Sigma F_z}{4} - \frac{M_r}{2L} + \frac{M_p}{2\ell} = \frac{F_{z1} + m_1 g + m_2 g}{4} - \frac{M_r}{2L} + \frac{M_p}{2\ell} \approx 252 \\ F_{r4} &= \frac{\Sigma F_z}{4} - \frac{M_r}{2L} - \frac{M_p}{2\ell} = \frac{F_{z1} + m_1 g + m_2 g}{4} - \frac{M_r}{2L} - \frac{M_p}{2\ell} \\ &\approx -1150 \\ F_{a1} &= F_{a3} = \frac{\Sigma F_y}{4} + \frac{M_y}{2\ell} = \frac{F_{y1}}{4} + \frac{M_y}{2\ell} \\ &= \frac{2000}{4} + \frac{220000}{2 \times 100} = 1600 \\ F_{a2} &= F_{a4} = \frac{\Sigma F_y}{4} - \frac{M_y}{2\ell} = \frac{F_{y1}}{4} - \frac{M_y}{2\ell} = -600 \end{aligned}$$

② Calculating of rating life

The upward / downward load and lateral load are converted by formula (6) and (7) on page III - 7.

$$\begin{aligned} F_{re1} &= k_r |F_{r1}| = 1 \times 1750 = 1750 \\ F_{re2} &= k_r |F_{r2}| = 1 \times 346 = 346 \\ F_{re3} &= k_r |F_{r3}| = 1 \times 252 = 252 \\ F_{re4} &= k_r |F_{r4}| = 1 \times 1150 = 1150 \\ F_{ae1} &= k_a |F_{a1}| = 1 \times 1600 = 1600 \\ F_{ae2} &= k_a |F_{a2}| = 1 \times 600 = 600 \\ F_{ae3} &= k_a |F_{a3}| = 1 \times 1600 = 1600 \\ F_{ae4} &= k_a |F_{a4}| = 1 \times 600 = 600 \end{aligned}$$

where, k_r, k_a : Conversion factors for load direction (See Table 3 on page III - 7.)

The dynamic equivalent load is calculated by formula (10) on page III - 7.

$$\begin{aligned} P_1 &= X |F_{re1}| + Y |F_{ae1}| = 1 \times 1750 + 0.6 \times 1600 = 2710 \\ P_2 &= X |F_{re2}| + Y |F_{ae2}| = 0.6 \times 346 + 1 \times 600 \approx 808 \\ P_3 &= X |F_{re3}| + Y |F_{ae3}| = 0.6 \times 252 + 1 \times 1600 \approx 1750 \\ P_4 &= X |F_{re4}| + Y |F_{ae4}| = 1 \times 1150 + 0.6 \times 600 = 1510 \end{aligned}$$

The basic rating life of slide unit 1 receiving the largest dynamic equivalent load is calculated. The basic rating life is obtained by the formula (1) given on the page III - 6 considering the load factor f_w (see Table 1 on page III - 6).

$$\begin{aligned} L_1 &= 50 \left(\frac{C}{f_w P_1} \right)^3 = 50 \times \left(\frac{18100}{1.5 \times 2710} \right)^3 \approx 4410 \\ L_{h1} &= \frac{10^6 L_1}{2 S n_1 \times 60} = \frac{10^6 \times 4410}{2 \times 100 \times 5 \times 60} \approx 73500 \end{aligned}$$

As the result of calculation above, the basic rating life is about 73,500 hours.

③ Calculating of static safety factor

The static equivalent load is calculated from the upward / downward load and lateral load by formula (11) on page III - 8.

$$\begin{aligned} P_{01} &= k_{0r} |F_{r1}| + k_{0a} |F_{a1}| = 1 \times 1750 + 1 \times 1600 = 3350 \\ P_{02} &= k_{0r} |F_{r2}| + k_{0a} |F_{a2}| = 1 \times 346 + 1 \times 600 = 946 \\ P_{03} &= k_{0r} |F_{r3}| + k_{0a} |F_{a3}| = 1 \times 252 + 1 \times 1600 = 1852 \\ P_{04} &= k_{0r} |F_{r4}| + k_{0a} |F_{a4}| = 1 \times 1150 + 1 \times 600 = 1750 \end{aligned}$$

where, k_{0r}, k_{0a} : Conversion factors for load direction (See Table 5 on page III - 8.)

The static safety factor of slide unit 1 receiving the largest static equivalent load is calculated. The static safety factor is calculated by formula (4) on page III - 6.

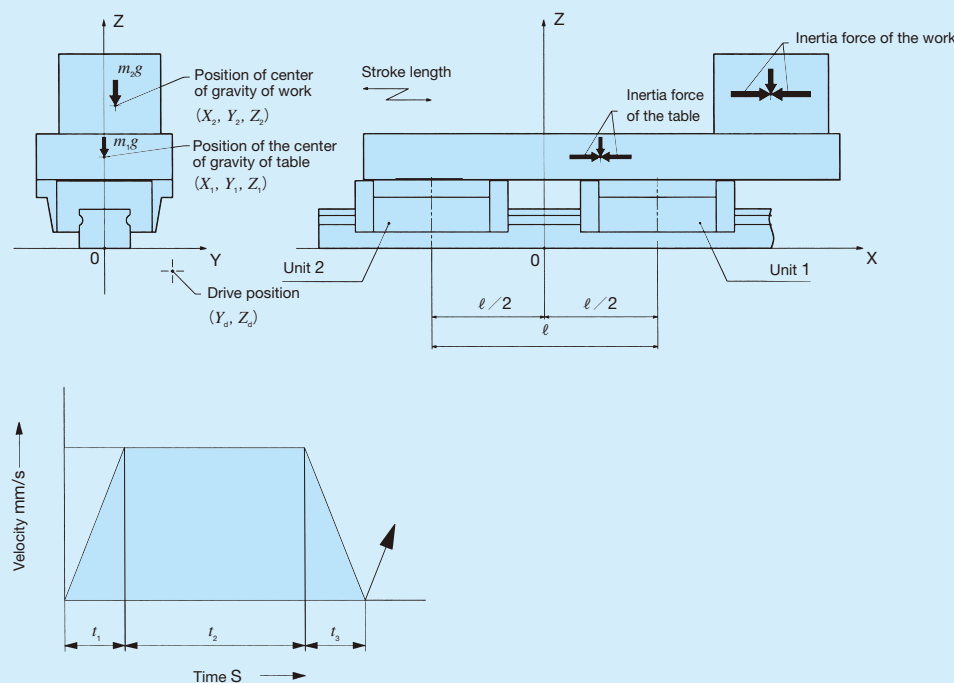
$$f_{s1} = \frac{C_0}{P_{01}} = \frac{21100}{3350} \approx 6.3$$

As the result of calculation above, the static safety factor is about 6.3.

Example 2

Linear Way Model·····MH 45 C2 R1050 H
Basic dynamic load rating····· $C = 74600$ N
Basic static load rating····· $C_0 = 80200$ N
Static moment rating in the T_0 direction····· $T_0 = 1610$ N · m
Table mass····· $m_1 = 100$ kg
Position of the center of gravity of table····· $X_1 = 50$ mm
····· $Y_1 = 0$ mm
····· $Z_1 = 80$ mm
Work mass····· $m_2 = 1000$ kg
Position of center of gravity of work····· $X_2 = 200$ mm
····· $Y_2 = 10$ mm
····· $Z_2 = 130$ mm

Distance between slide units····· $\ell = 200$ mm
Stroke length····· $S = 500$ mm
Number of strokes per minute····· $n_1 = 6$ cpm
Maximum traveling velocity····· $V = 100$ mm/s
Time spent for acceleration····· $t_1 = 0.1$ s
Time spent during constant speed motion····· $t_2 = 4.9$ s
Time spent for deceleration····· $t_3 = 0.1$ s
Drive position····· $Y_d = 60$ mm
····· $Z_d = -20$ mm



The life and static safety factor in the case of Example 2 is calculated. Load factor f_w is assumed to be 1.5.

① Calculation of load on the slide unit

Due to the applied load and the table mass and inertia force, moment load occurs around each coordinate axis of the Linear Way as shown below.

(During acceleration at the start of motion)

$$M_r = \sum (F_y Z) + \sum (F_z Y) = m_1 g Y_1 + m_2 g Y_2 = 100 \times 9.8 \times 0 + 1000 \times 9.8 \times 10 \div 98000$$

$$M_p = \sum \{F_x (Z - Z_d)\} + \sum (F_z X) \\ = m_1 \frac{V_{\max}}{1000 \times t_1} (Z_1 - Z_d) + m_2 \frac{V_{\max}}{1000 \times t_1} (Z_2 - Z_d) + m_1 g X_1 + m_2 g X_2 \\ = 100 \times \frac{100}{1000 \times 0.1} \times (80 + 20) + 1000 \times \frac{100}{1000 \times 0.1} \times (130 + 20) + 100 \times 9.8 \times 50 + 1000 \times 9.8 \times 200 \div 2169000$$

$$M_y = -\sum \{F_x (Y - Y_d)\} + \sum (F_y X) \\ = -m_1 \frac{V_{\max}}{1000 \times t_1} (Y_1 - Y_d) - m_2 \frac{V_{\max}}{1000 \times t_1} (Y_2 - Y_d) \\ = -100 \times \frac{100}{1000 \times 0.1} \times (0 - 60) - 1000 \times \frac{100}{1000 \times 0.1} \times (10 - 60) \div 56000$$

(During constant speed motion)

$$M_r = m_1 g Y_1 + m_2 g Y_2 \div 98000$$

$$M_p = m_1 g X_1 + m_2 g X_2 \div 2010000$$

$$M_y = 0$$

(During deceleration at the end of motion)

$$M_r = m_1 g Y_1 + m_2 g Y_2 \div 98000$$

$$M_p = -m_1 \frac{V_{\max}}{1000 \times t_3} (Z_1 - Z_d) - m_2 \frac{V_{\max}}{1000 \times t_3} (Z_2 - Z_d) + m_1 g X_1 + m_2 g X_2 \div 1850000$$

$$M_y = m_1 \frac{V_{\max}}{1000 \times t_3} (Y_1 - Y_d) + m_2 \frac{V_{\max}}{1000 \times t_3} (Y_2 - Y_d) \div -56000$$

where, M_r : Moment load in the rolling direction, N · mm
 M_p : Moment load in the pitching direction, N · mm
 M_y : Moment load in the yawing direction, N · mm

The loads applied on each slide unit are calculated according to Table 6.2 on page III-9.

(During acceleration at the start of motion)

$$F_{r1} = \frac{\sum F_z + \frac{M_p}{\ell}}{2} = \frac{m_1 g + m_2 g}{2} + \frac{M_p}{\ell} \\ = \frac{100 \times 9.8 + 1000 \times 9.8}{2} + \frac{2169000}{200} \div 16200$$

$$F_{r2} = \frac{\sum F_z + \frac{M_p}{\ell}}{2} = \frac{m_1 g + m_2 g}{2} - \frac{M_p}{\ell} \div -5460$$

$$F_{a1} = \frac{\sum F_y + \frac{M_y}{\ell}}{2} = 280$$

$$F_{a2} = \frac{\sum F_y - \frac{M_y}{\ell}}{2} = -280$$

$$M_{01} = M_{02} = \frac{M_r}{2} = 49000$$

(During constant speed motion)

$$F_{r1} = \frac{100 \times 9.8 + 1000 \times 9.8}{2} + \frac{2010000}{200} \div 15400$$

$$F_{r2} \div -4660$$

$$F_{a1} = F_{a2} = 0$$

$$M_{01} = M_{02} = 49000$$

(During deceleration at the end of motion)

$$F_{r1} = \frac{100 \times 9.8 + 1000 \times 9.8}{2} + \frac{1850000}{200} \div 14600$$

$$F_{r2} \div -3860$$

$$F_{a1} \div -280$$

$$F_{a2} \div 280$$

$$M_{01} = M_{02} = 49000$$

② Calculating of rating life

The upward / downward load, lateral load and the moment load along T_0 direction are calculated by the formula (6) and (7) on page III-7, and the dynamic equivalent load is calculated by formula (10).

(During acceleration at the start of motion)

$$F_{re1} = k_r |F_{r1}| + \frac{C_0}{T_0} |M_{01}| = 1 \times 16200 + \frac{80200}{1610} \times \frac{49000}{1000} \div 18600$$

$$F_{re2} = 1 \times 5460 + \frac{80200}{1610} \times \frac{49000}{1000} \div 7900$$

$$F_{ae1} = k_a |F_{a1}| = 1.28 \times 280 \div 358$$

$$F_{ae2} = 1.28 \times 280 \div 358$$

$$P_{1a} = X F_{re1} + Y F_{ae1} = 1 \times 18600 + 0.6 \times 358 \div 18800$$

$$P_{2a} = X F_{re2} + Y F_{ae2} = 1 \times 7900 + 0.6 \times 358 \div 8110$$

(During constant speed motion)

$$F_{re1} = 1 \times 15400 + \frac{80200}{1610} \times \frac{49000}{1000} \div 17800$$

$$F_{re2} = 1 \times 4660 + \frac{80200}{1610} \times \frac{49000}{1000} \div 7100$$

$$F_{ae1} = 0$$

$$F_{ae2} = 0$$

$$P_{1b} = 17800$$

$$P_{2b} = 7100$$

(During deceleration at the end of motion)

$$F_{re1} = 1 \times 14600 + \frac{80200}{1610} \times \frac{49000}{1000} \div 17000$$

$$F_{re2} = 1 \times 3860 + \frac{80200}{1610} \times \frac{49000}{1000} \div 6300$$

$$F_{ae1} = 1.28 \times 280 \div 358$$

$$F_{ae2} = 1.28 \times 280 \div 358$$

$$P_{1c} = 1 \times 17000 + 0.6 \times 358 \div 17200$$

$$P_{2c} = 1 \times 6300 + 0.6 \times 358 \div 6510$$

Because the dynamic equivalent load changes stepwise along the traveling distance, the mean equivalent load is calculated from ① in Table 7 on page III-14.

$$P_{m1} = \sqrt[3]{\frac{1}{S} \left(P_{1a}^3 \frac{V_{\max} t_1}{2} + P_{1b}^3 V_{\max} t_2 + P_{1c}^3 \frac{V_{\max} t_3}{2} \right)} \\ = \left\{ \frac{1}{500} \times \left(18800^3 \times \frac{100 \times 0.1}{2} + 17800^3 \times 100 \times 4.9 + 17200^3 \times \frac{100 \times 0.1}{2} \right) \right\}^{1/3} \div 17800$$

$$P_{m2} = \left\{ \frac{1}{500} \times \left(8110^3 \times \frac{100 \times 0.1}{2} + 7100^3 \times 100 \times 4.9 + 6510^3 \times \frac{100 \times 0.1}{2} \right) \right\}^{1/3} \div 7110$$

The basic rating life of slide unit 1 receiving the largest dynamic equivalent load is calculated. The basic rating life is obtained by the formula (1) given on the page III-6 considering the load factor f_w (see Table 1 on page III-6).

$$L_1 = 50 \left(\frac{C}{f_w P_{m1}} \right)^3 = 50 \left(\frac{74600}{1.5 \times 17800} \right)^3 \div 1090$$

$$L_{h1} = \frac{10^6 L_1}{2S n_1 \times 60} = \frac{10^6 \times 1090}{2 \times 500 \times 6 \times 60} \div 3030$$

As the result of calculation above, the basic rating life is about 3,030 hours.

③ Calculating of static safety factor

The static equivalent load is calculated from the upward / downward load and lateral load by formula (11) on page III-8.

(During acceleration at the start of motion)

$$P_{01a} = k_{0r} |F_{r1}| + k_{0a} |F_{a1}| + \frac{C_0}{T_0} |M_{01}| = 1 \times 16200 + 1.28 \times 280 + \frac{80200}{1610} \times \frac{49000}{1000} \div 19000$$

$$P_{02a} = k_{0r} |F_{r2}| + k_{0a} |F_{a2}| + \frac{C_0}{T_0} |M_{02}| = 1.19 \times 5460 + 1.28 \times 280 + \frac{80200}{1610} \times \frac{49000}{1000} \div 9300$$

(During constant speed motion)

$$P_{01b} = 1 \times 15400 + 1.28 \times 0 + \frac{80200}{1610} \times \frac{49000}{1000} \div 19000$$

$$P_{02b} = 1.19 \times 4660 + 1.28 \times 0 + \frac{80200}{1610} \times \frac{49000}{1000} \div 7990$$

(During deceleration at the end of motion)

$$P_{01c} = 1 \times 14600 + 1.28 \times 280 + \frac{80200}{1610} \times \frac{49000}{1000} \div 17400$$

$$P_{02c} = 1.19 \times 3860 + 1.28 \times 280 + \frac{80200}{1610} \times \frac{49000}{1000} \div 7390$$

The static safety factor of slide unit 1 during acceleration at the start of motion receiving the largest static equivalent load is calculated. The static safety factor is calculated by formula (4) on page III-6.

$$f_s = \frac{C_0}{P_{01a}} = \frac{80200}{19000} \div 4.2$$

As the result of calculation above, the static safety factor is about 4.2.

Accuracy

Five classes of accuracy, ordinary, high, precision, super precision, and ultra precision are specified for Linear Way and Linear Roller Way.

The outline of applicable accuracy classes is shown in Table 8. For details, see an explanation of each series.

Table 8 Accuracy classes and series

Class (classification symbol)	Ordinary (No symbol)	High (H)	Precision (P)	Super precision (SP)	Ultra precision (UP)
Series name					
C-Lube Linear Way ML Linear Way L	—	○	○	—	—
C-Lube Linear Way MLV	—	○	—	—	—
C-Lube Linear Way MV	○	○	○	○	—
C-Lube Linear Way ME Linear Way E	○	○	○	○	—
C-Lube Linear Way MH Linear Way H	—	○	○	○	—
Linear Way F	—	○	○	○	—
C-Lube Linear Way MUL Linear Way U	○	○	—	—	—
C-Lube Linear Roller Way Super MX Linear Roller Way Super X	—	○	○	○	○
Linear Roller Way X	—	○	○	○	○
Linear Way Module	—	○	○	○	—

Preload

Objectives of preload

In some cases, the linear motion rolling guide is used with clearance given to the linear motion rolling guide when light motion with small load is required. However, for some applications, it may be used with play in the guiding mechanism removed or with preload to increase rigidity. Preload is applied to the contact parts of a raceway and rolling elements with internal stress generated in advance. When a external load is applied on the preloaded linear motion rolling guide, shock absorbing with this internal stress makes elastic deformation smaller, and its rigidity is increased. (See Fig. 3)

Preload setting

Preload amount is determined by considering the characteristics of the machines or equipments on which the linear motion rolling guide is mounted and the nature of load acting on the linear motion rolling guide. The standard amount of preload for linear motion rolling guides is, in general, approx. 1/3 of load when the rolling elements are balls (steel balls) and approx. 1/2 of load when they are rollers (cylindrical rollers). If the linear motion rolling guides are required to have very high rigidity to withstand vibration or fluctuating load, a larger preload may be applied. For applicable preload amount, see Table 9. For details, see an explanation of each series.

Precaution for preload selection

Even when high rigidity must be required, excessive preload should be avoided, because it will produce an excessive stress between rolling elements and raceways, and eventually result in short life of linear motion rolling guides. It is important to apply a proper amount of preload, considering the operational conditions. When using with a large preload, contact **IKO**.

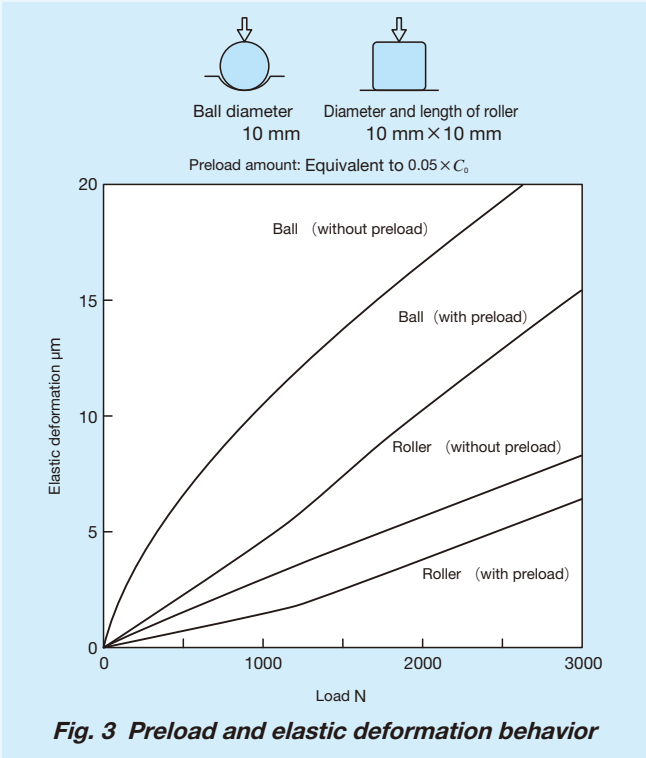


Table 9 Series and preload amount

Preload (preload symbol)	Clearance (T _c)	Clearance (T ₀)	Standard (No symbol)	Light preload (T ₁)	Medium preload (T ₂)	Heavy preload (T ₃)
Series name						
C-Lube Linear Way ML Linear Way L	—	○	○	○	—	—
C-Lube Linear Way MLV ⁽¹⁾	—	—	—	—	—	—
C-Lube Linear Way MV	○	—	○	○	—	—
C-Lube Linear Way ME Linear Way E	○	—	○	○	○	—
C-Lube Linear Way MH Linear Way H	—	○	○	○	○	○
Linear Way F	—	—	○	○	○	—
C-Lube Linear Way MUL Linear Way U	—	—	○	○	—	—
C-Lube Linear Roller Way Super MX Linear Roller Way Super X	—	—	○	○	○	○
Linear Roller Way X	—	—	○	○	○	○

Note ⁽¹⁾ Preload is adjusted to have subtle clearance or minimal amount of preload.

Friction

Friction of linear motion rolling guide

The static friction (start-up friction) of linear motion rolling guides is much lower than that of conventional plain guides. Also, the difference between static friction and dynamic friction is small, and frictional resistance varies little when velocity changes. These are excellent features of linear motion rolling guides, and account for their ability to reduce power consumption, suppress operating temperature rise, and increase traveling speed. Since frictional resistance and variation are small, high-speed response characteristics to motion commands and high accuracy positioning can be achieved.

Friction coefficient

The frictional resistance of linear motion rolling guides varies with their model, applied load, velocity and characteristics of lubricant. Generally, lubricant or seals are major factors in determining the frictional resistance in light load or high-speed operation, while the amount of load is the major factor in heavy load or low speed operation. The frictional resistance of linear motion rolling guides depends on various factors, but generally the following formula is used.

$$F=\mu P \cdots \cdots \cdots (13)$$

where, F : Frictional resistance, N
 μ : Dynamic friction coefficient
 P : Applied load, N

For sealed guides, seal resistance is added to the above value, but this resistance varies greatly depending on the interference amount of seal lip and lubrication conditions. Where the lubrication and mounting condition are correct and the load is moderate, the friction coefficients of Linear Way and Linear Roller Way in operation are within the range shown in Table 10. Generally, friction coefficient is large under small load.

Table 10 Friction coefficient

Series name	Dynamic friction coefficient μ ⁽¹⁾
Linear Way	0.0040～0.0060
Linear Roller Way	0.0020～0.0040

Note ⁽¹⁾ These friction coefficients do not include seal.

Lubrication

Objectives of lubrication

The objectives of applying lubricant for linear motion rolling guides is to keep raceways, rolling elements, etc. in a linear motion rolling guide from metal contact, and thereby reduce friction and wear preventing heat generation and seizure. When an adequate oil film is formed at the rolling contact area between the raceways and rolling elements, the contact stress due to load can be reduced. To manage the formation of adequate oil film is important for ensuring the reliability of linear motion rolling mechanism.

Selection of lubricant

To obtain the full performance of linear motion rolling guides, it is necessary to select an appropriate lubricant and lubrication method by considering the model, load and velocity of each linear motion rolling guide. However, as compared with plain guides, lubrication of linear motion rolling guides is much simpler. Only a small amount of lubrication oil is needed and replenishment interval is longer, so maintenance can be greatly reduced. Grease and oil are the two most commonly used lubricants for linear motion rolling guides.

Grease lubrication

For linear motion rolling guides, lithium-soap base grease (Consistency No.2 of JIS) is commonly used. For rolling guides operating under heavy load conditions, grease containing extreme pressure additives is recommended. In clean and high-vacuum environments, where low dust generating performance and low vaporization characteristics are required, greases containing a synthetic-base oil or a soap other than the lithium-soap base are used. For applications in these environments, due consideration is necessary to select a grease that is suitable for the operating conditions of linear motion rolling guide and achieves satisfactory lubrication performance at the same time.

Table 11 Pre-packed grease list

Series name	Pre-packed grease
C-Lube Linear Way ML Linear Way L	MULTEMP PS No.2 [KYODO YUSHI CO., LTD.]
C-Lube Linear Way MLV	
C-Lube Linear Way MV	Alvania EP Grease 2 [SHOWA SHELL SEKIYU K. K.]
C-Lube Linear Way ME Linear Way E	
C-Lube Linear Way MH ⁽¹⁾ Linear Way H ⁽¹⁾	
Linear Way F	
C-Lube Linear Way MUL Linear Way U ⁽²⁾	MULTEMP PS No.2 [KYODO YUSHI CO., LTD.]
C-Lube Linear Roller Way Super MX Linear Roller Way Super X	Alvania EP Grease 2 [SHOWA SHELL SEKIYU K. K.]
Linear Roller Way X	
Linear Way Module	

Notes ⁽¹⁾ MULTEMP PS No.2 is pre-packed in size 8 to 12 series.
⁽²⁾ Alvania EP Grease 2 is pre-packed in size 40 to 86 series.

Grease replenishment interval

The quality of any grease will gradually deteriorate as operating time passes. Therefore, periodic replenishment is necessary. Grease replenishment interval varies depending on the operating conditions. A six month interval is generally recommended, and if the machine operation consists of reciprocating motions with many cycles and long strokes, replenishment every three month is recommended. In addition, linear motion rolling guides in which the lubrication part "C-Lube" is built deliver long-term maintenance free performance. This eliminates the need for lubrication mechanism and workload which used to be necessary for linear motion rolling guides and significantly reduces maintenance cost.

Grease replenishment method

New grease must be supplied through a grease feed device such as a grease nipple until old grease is discharged. After grease is replenished, running-in is performed and excess grease will be discharged to outside of the linear motion rolling guide. Discharged grease must then be removed before starting the operation. The amount of grease required for standard replenishment is about 1/3 to 1/2 of the free space inside the linear motion rolling guide. When grease is supplied from a grease nipple for the first time, there will be grease lost in the replenishment path. The amount lost should be taken into consideration. Generally, immediately after grease is replenished, frictional resistance tends to increase. If additional running-in is performed for 10 to 20 reciprocating cycles after excess grease is discharged, frictional resistance becomes small and stable. For applications where low frictional resistance is required, the replenishment amount of grease may be reduced, but it must be kept to an appropriate level so as not to give a bad influence on the lubrication performance.

Table 12 Grease brands used in linear motion rolling guide

Brand		Base oil	Thickener	Consistency	Range of operating temperature ⁽²⁾ ℃	Usage
Alvania EP Grease 2	[SHOWA SHELL SEKIYU K. K.]	Mineral oil	Lithium	284	-20～110	General application with extreme-pressure additive
Alvania Grease S2	[SHOWA SHELL SEKIYU K. K.]	Mineral oil	Lithium	283	-25～120	General application
MULTEMP PS No.2	[KYODO YUSHI CO., LTD.]	Synthetic oil, Mineral oil	Lithium	275	-50～130	General application
IKO Low Dust-Generation Grease for Clean Environment CG2	[NIPPON THOMPSON CO., LTD.]	Synthetic oil	Urea	280	-40～200	For clean environment Long life
IKO Low Dust-Generation Grease for Clean Environment CGL	[NIPPON THOMPSON CO., LTD.]	Synthetic oil, Mineral oil	Lithium / Calcium	225	-30～120	For clean environment Low sliding
DEMNUM™ Grease L-200 ⁽¹⁾	[DAIKIN INDUSTRIES, LTD.]	Synthetic oil	Ethylene tetra-fluoride	280	-60～300	For clean environment
Klüberalfa GR Y-VAC3 ⁽¹⁾	[NOK KLUEBER]	Synthetic oil	Ethylene tetra-fluoride	No.3	-20～250	For vacuum
IKO Anti-Fretting Corrosion Grease AF2	[NIPPON THOMPSON CO., LTD.]	Synthetic oil	Urea	285	-50～170	Fretting-proof
6459 Grease N	[SHOWA SHELL SEKIYU K. K.]	Mineral oil	Poly-urea	305	—	Fretting-proof

Notes ⁽¹⁾ Set replenishment intervals to short.
⁽²⁾ The ranges of operating temperature are quoted from the grease manufacturer's cataloged values, but do not guarantee regular use under high temperature environment.
Remarks 1. DEMNUM™ is a trademark of DAIKIN INDUSTRIES.
2. Check with the chosen grease manufacturer's catalog before use.
For grease for use other than listed, contact **IKO**.

Mixing of different type of grease

Mixing different types of grease may result in changing the properties of base oil, soap base, or additives used, and, in some cases, severely deteriorate the lubrication performance or cause trouble due to chemical changes of additives. Old grease should therefore be removed thoroughly before filling with new grease.

Lubrication part "C-Lube"

C-Lube is a porous resin with molding formed fine resin powder. It is a lubrication part impregnated with a large amount of lubrication oil in its open pores by capillary inside. Lubrication oil is supplied directly to balls (steel balls) or rollers (cylindrical rollers), not to the track rail. When the balls or rollers have contact with C-Lube built in the slide unit, lubrication oil is supplied to the surface of the balls or rollers. As the balls or rollers circulate, the lubricant is distributed to the loading area along the track rail. This results in adequate lubrication oil being properly maintained in the loading area and lubrication performance will last for a long time. The surface of C-Lube is always covered with the lubrication oil. Lubrication oil is continuously supplied to the surface of balls or rollers by surface tension in the contact of C-Lube surface and balls or rollers.

Oil lubrication

For oil lubrication, heavy load requires high oil viscosity and high velocity requires low oil viscosity. Generally, for linear motion rolling guides operating under heavy load, lubrication oil with a viscosity of about 68 mm²/s is used. For linear motion rolling guides under light load at high-speed operation, lubrication oil with a viscosity of about 13 mm²/s is used.

Miniature greaser

The miniature greaser is specially prepared for grease replenishment for Linear Way and Linear Roller Way with an oil hole. Table 13 shows types of grease and specifications of miniature greasers.



Table 13 Grease type and miniature greaser

Identification number	Grease name	Amount	Outer diameter of grease feed needle
MG10 / MT2	MULTEMP PS No.2 [KYODO YUSHI CO., LTD.]	10 ml	φ 1 mm
MG10 / CG2	IKO Low Dust-Generation Grease for Clean Environment CG2		
MG2.5 / EP2	Alvania EP Grease 2 [SHOWA SHELL SEKIYU K. K.]	2.5 ml	
MG2.5 / CG2	IKO Low Dust-Generation Grease for Clean Environment CG2		
MG2.5 / CGL	IKO Low Dust-Generation Grease for Clean Environment CGL		
MG2.5 / AF2	IKO Anti-Fretting Corrosion Grease AF2		

Grease nipple and supply nozzle

Tables 14.1 and 14.2 show the specifications of grease nipples and applicable types of supply nozzles, and Table 15 shows the specifications of supply nozzles.

Table 14.1 Grease nipple and applicable supply nozzle type

Grease nipple		Applicable supply nozzle type	
Type	Dimensions and shape	Type	Shape
A-M3		A-5120V A-5240V B-5120V B-5240V	
A-M4			
B-M4		A-8120V B-8120V	

Table 14.2 Grease nipple and applicable supply nozzle type

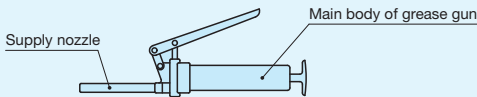
Grease nipple		Applicable supply nozzle type	
Type	Dimensions and shape	Type	Shape
B-M6		Products available on the market	
JIS type 1			
JIS type 2			
JIS type 4			
A-PT 1/4			

Note (1) For straight type, chuck type and hose type supply nozzles available on the market, it is recommended to use one with an outer diameter D of 13 mm or less.

Table 15 Types and dimensions of supply nozzle

Type	Dimensions and shape
A-5120V	
A-5240V	
B-5120V	
B-5240V	
A-8120V	
B-8120V	

Remark: The supply nozzles shown in the table can be mounted on the main body of a common grease gun available on the market shown below. If needed, specify the supply nozzle type and place an order to **IKO**.



Piping joint

When applying centralized grease or oil lubrication, detach the grease nipple or plug from the slide unit, and replace them with piping joints, which are prepared for various female threads for piping. Use them after confirming the dimensions of the piping joints and H_3 dimensions in the dimensions table of each models, because the top face of some piping joints is at the same or higher level than the top face of slide unit. Fig. 4.1 and 4.2 and Tables 16.1, 16.2, 16.3, and 16.4 show identification number and dimensions of piping joints. Note that some of them are not applicable for the slide units of special specifications. Piping joints can be mounted on Linear Way and Linear Roller Way prior to delivery upon request. If needed, please contact **IKO**.

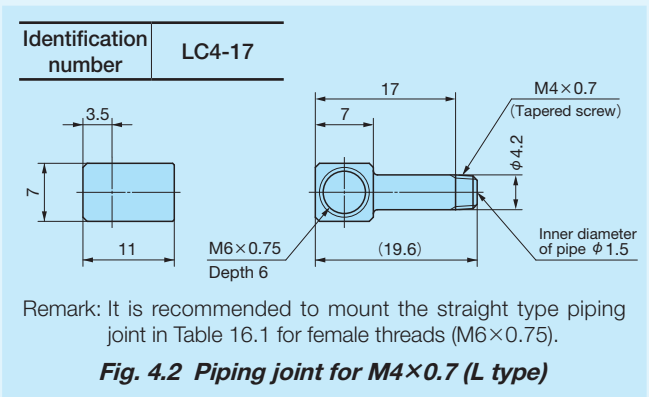
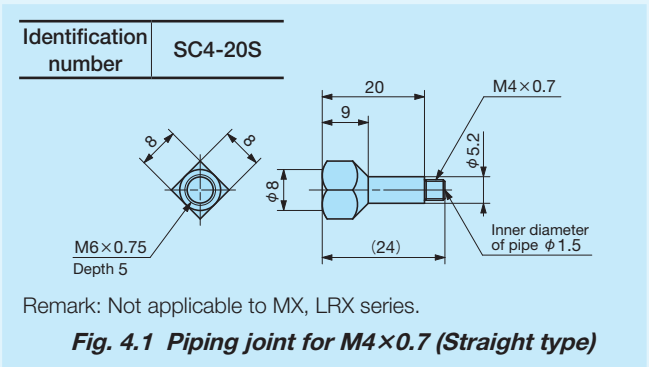


Table 16.1 Piping joint for M6×0.75 (Straight type)

		unit: mm			
Identification number	L_1	L_2	L_3	D	
SC6-16	22	12.4	16	9	
SC6-22S	28	12	22	6	
SC6-25S	31	12	25	6	

Table 16.2 Piping joint for M6×0.75 (L type)

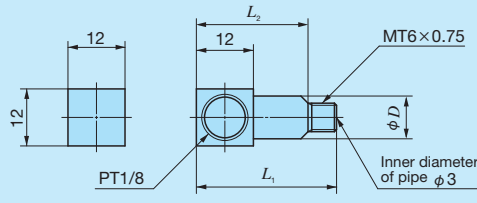
			
Identification number	L_1	L_2	D
LC6-18	25	18	9
LC6-22S	28	—	6
LC6-24	30.5	23.5	9
LC6-25S	31	—	6

Table 16.3 Piping joint for PT1/8 (Straight type)

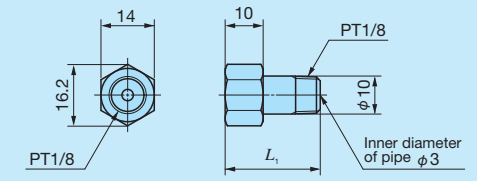
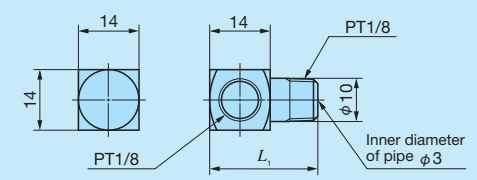
	
Identification number	L_1
SC1/8-19S	25
SC1/8-34S	40

Table 16.4 Piping joint for PT1/8 (L type)

	
Identification number	L_1
LC1/8-19S	25
LC1/8-34S	40

Dust Protection

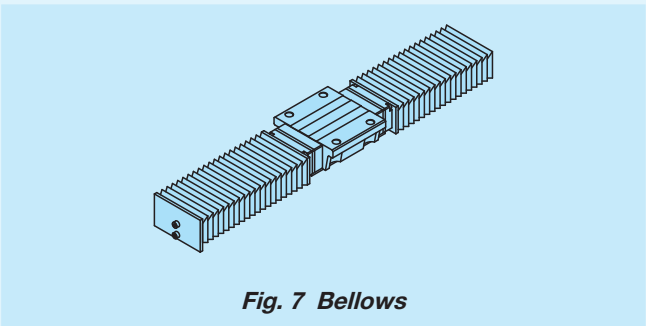
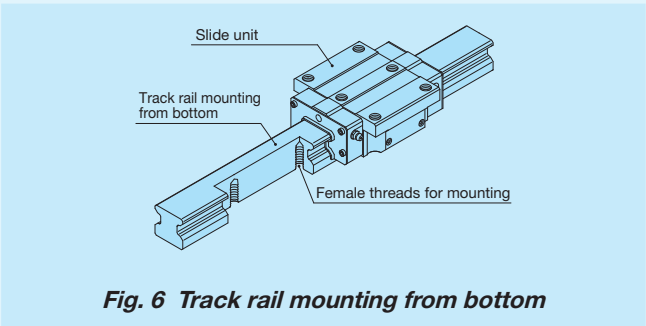
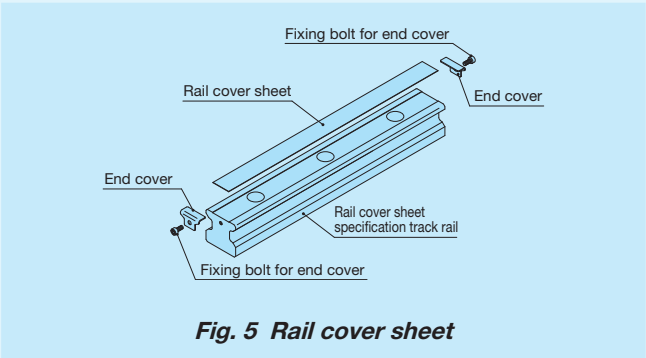
Purpose of dust protection

To obtain the full performance of linear motion rolling guides, it is important to protect them from the intrusion of dust and other harmful foreign substances. Select an effective sealing or dust-protection device to withstand any operating conditions that might be imposed.

Method of dust protection

Linear Way and Linear Roller Way have end seals as a standard specification. In addition, double seals or scrapers are provided as special specifications for improvement in dust protection performance. Also caps and a rail cover sheet to cover the mounting hole of track rail (Fig. 5) and track rail mounting from bottom with no mounting hole on the upper surface (Fig. 6) will further increase the reliability of dust protection.

However, if large amount of contaminant or dust are floating, or if large particles of foreign substances such as chips or sand may adhere to the raceway, complete dust protection becomes difficult. In this case, it is recommended to cover the whole unit with bellows (Fig. 7), telescope type shield, etc. When rail cover sheet or track rails mounting from bottom specification is needed, please contact **IKO**.

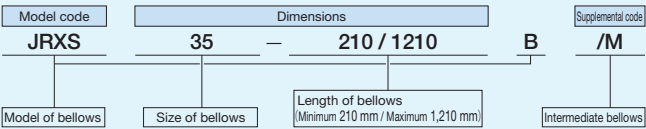


Specific bellows

The specific bellows are manufactured to match the dimensions of Linear Way and Linear Roller Way for easy mounting and excellent dust protection. If special bellows to be used in an upside-down position or those made of heat-resistant material are needed, please contact **IKO**.

Identification number of bellows

The identification number of bellows consists of a model code, dimensions, and any supplemental codes. Its standard arrangement is shown below.



Calculation of minimum length of bellows

The minimum necessary length of specific bellows is determined, by first calculating the necessary number of accordion pleats as follows.

$$ns = \frac{S}{\ell s_{\max} - \ell s_{\min}}$$

where, ns : Number of pleats (Raise decimal fractions)
 S : Stroke length, mm
 $\ell s_{\max}$: Maximum length of one pleat (See Tables 18.1 and 18.2)
 $\ell s_{\min}$: Minimum length of one pleat (See Tables 18.1 and 18.2)

$$L_{\min} = ns \times \ell s_{\min} + m \times 5 + 10$$
$$L_{\max} = S + L_{\min}$$

where, $L_{\min}$: Minimum length of bellows, mm
 $L_{\max}$: Maximum length of bellows, mm
 m : Number of internal guide plates (See Table 17)

Table 17 Number of internal guide plates for bellows

Model	P dimensions of specific bellows ⁽¹⁾ mm		Number of internal guide plates m
	Above	Below	
JEF JRES	—	35	$m = \frac{ns}{7} - 1$
JES JHS JFS JRXS···B JFFS	—	22	$m = \frac{ns}{16}$ when $ns \leq 20$, then $m=0$
	22	25	$m = \frac{ns}{12}$ when $ns \leq 18$, then $m=0$
	25	35	$m = \frac{ns}{8}$

Note ⁽¹⁾ For P dimensions, see Table 18.1 and Table 18.2.
Remark: In calculating the number of internal guide plates m , raise the decimal fractions for JEF and JRES and omit the decimal fractions for others.

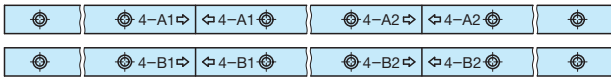
Intermediate bellows

Since different type of mounting plate is used for mounting bellows between slide units, add supplemental code "/M" onto the identification number when ordering. Reinforced bellows are also available, which are specially designed for use on long track rails or for lateral mounting. The width A of reinforced bellows is greater than that of standard type bellows. If needed, please contact **IKO**.

Special Specification

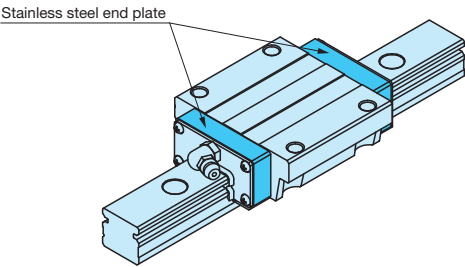
For Linear Way and Linear Roller Way, special specification described in pages Ⅲ-29 through Ⅲ-35 is available. There is limitation on applicable special specification. For details, see an explanation of each series.

Butt-jointing track rails /A



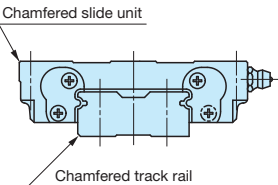
When the track rail of non-interchangeable specification is longer than the maximum length, two or more track rails should be butt-jointed in a linear motion direction. For length and number of track rails to butt, contact **IKO**.

Stainless steel end plate /BS



The standard synthetic resin end plates are replaced with stainless steel end plates. The total length of the slide unit remains unchanged. In addition, for improvement of heat resistance, it is recommended to use "No end seal (supplemental code /N)" together.

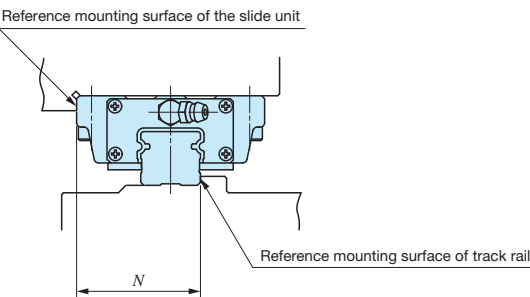
Chamfered reference surface /C /CC



Add chamfer to the reference mounting surface of the slide unit and track rail.

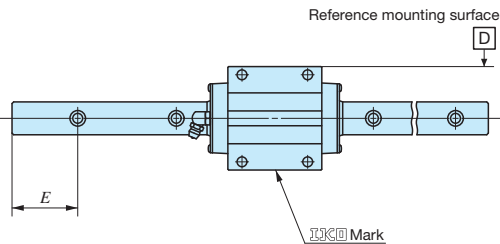
- ① /C Add chamfer to the reference mounting surface of the track rail.
- ② /CC Add chamfer to the reference mounting surface of the slide unit and track rail.

Opposite reference surfaces arrangement /D



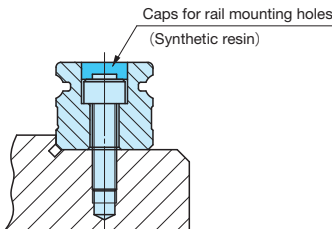
Reference mounting surface of the track rail should be the opposite of the standard position. Accuracy of N dimensions and parallelism during operation remain unchanged.

Specified rail mounting hole positions /E



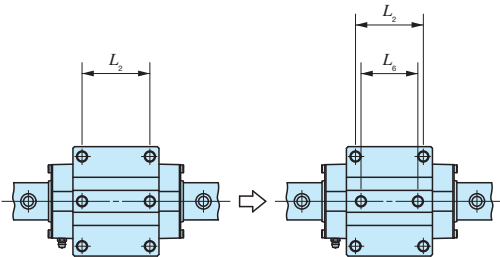
By specifying E dimensions from the mounting hole at the track rail left end to the left end surface when seen from **IKO** mark of the slide unit, specify the position of track rail mounting hole. Specify the dimensions (in mm) after "/E". In addition, E dimension range is limited. For details, please contact **IKO**. For Linear Way H horizontal mounting type and Linear Way Module series, see an explanation of each series.

Caps for rail mounting holes /F



Dedicated caps for rail mounting holes are included. They close track rail mounting holes to improve sealing property in a motion direction. Contact **IKO** for aluminum alloy caps for rail mounting holes.

Changed pitch of slide unit middle mounting holes /GE

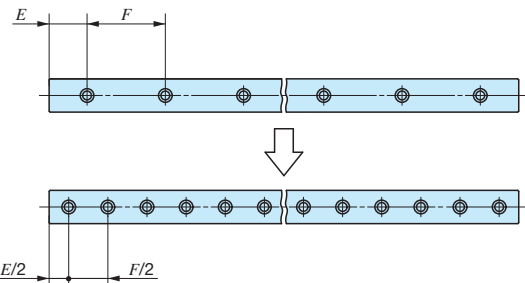


Change the dimension between mounting holes at the slide unit center.

Hybrid C-Lube Linear Way /HB

Change the material of rolling elements built into the slide unit to silicon nitride ceramics.

Half pitch mounting holes for track rail /HP

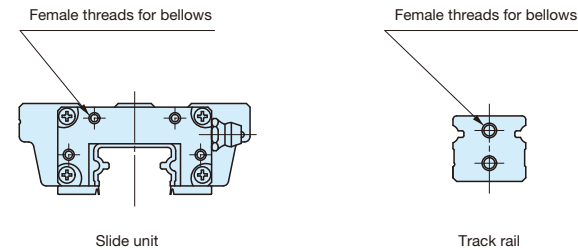


Set the pitch of track rail mounting holes to a half of the standard F dimension. The specification with bolts for track rail mounting holes are supplied with the required number of bolts.

Inspection sheet / I

Inspection sheet of *H* dimension, *N* dimension and parallelism during slide unit operation are appended in each set.

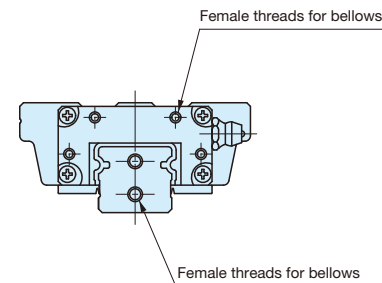
Female threads for bellows (Single unit) /J /JR /JL



For single slide unit or single track rail of the interchangeable specification, fit female threads for bellows.

- ① /J Fit female threads to both ends of the slide unit or track rail.
- ② /JR Fit female threads to a right end surface of the slide unit seen from  mark of the slide unit.
- ③ /JL Fit female threads to a left end surface of the slide unit seen from  mark of the slide unit.

Female threads for bellows (Assembled set) /J /JJ /JR /JS /JJS



For assembled set of the interchangeable specification or a non-interchangeable specification product, fit female threads for bellows to the slide unit and track rail.

- ① /J Fit female threads to both ends of the track rail and to slide unit end nearest to both ends of the track rail. (When only one slide unit is used, fit them to both ends of the track rail)
- ② /JJ When two or more slide units are used, fit female threads to both ends of the track rail and to both ends of each slide unit. (When only one slide unit is used, specify "/J")
- ③ /JR Fit female threads to both ends of the track rail.
- ④ /JS Fit female threads to slide unit end nearest to both ends of the track rail. (When only one slide unit is used, they are fitted to both ends of the track rail)
- ⑤ /JJS When two or more slide units are used, fit female threads to both ends of each slide unit. (When only one slide unit is used, specify "/JS")

Black chrome surface treatment /LC /LR /LCR

Acrylate resin coating is applied to improve the rust prevention property after black impregnated chrome surface treatment.

- ① /LC Perform casing treatment.
- ② /LR Perform track rail treatment.
- ③ /LCR Perform casing and track rail treatment.

Fluorine black chrome surface treatment /LFC /LFR /LFCR

Fluorinated resin coating is applied to improve the rust prevention property after black impregnated chrome surface treatment. In addition, this prevent foreign substances from sticking to the surface.

- ① /LFC Perform casing treatment.
- ② /LFR Perform track rail treatment.
- ③ /LFCR Perform casing and track rail treatment.

With track rail mounting bolt /MA

Recommended track rail mounting bolt is included. For bolt size, see the dimension table.

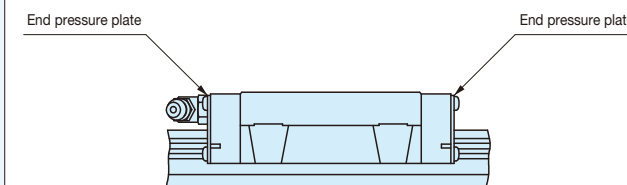
Without track rail mounting bolt /MN

Track rail mounting bolt is not included.

Changed size of mounting holes /M4

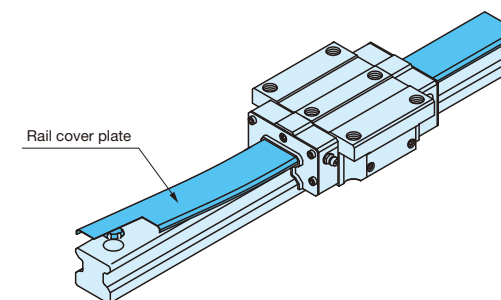
Set the M3 track rail mounting hole for ME15 to M4 track rail mounting holes. For combination with track rail mounting bolt (supplemental code "/MA"), specify "/MA4".

No end seal /N



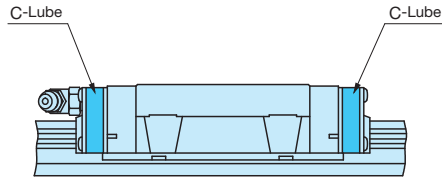
End seals at both ends of the slide unit can be replaced with end pressure plates, which do not come in contact with the track rail, to reduce frictional resistance. No under seal is attached.
This specification is not effective for dust protection.

Rail cover plate for track rail /PS



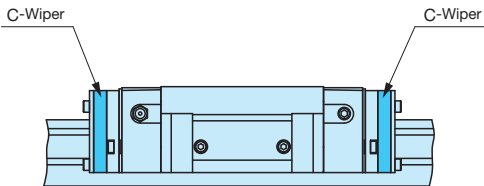
Deliver with the track rail cover plate mounted. Covering the upper surface with U-shape stainless steel thin plate after assembly of the track rail improves the sealing property further. Change the end seal to dedicated one.
In addition, see the supplied rail cover plate instruction manual for mounting of rail cover plate.

With C-Lube plate /Q



The C-Lube impregnated with lubricant is attached inside the end seal of the slide unit, so that the interval for reapplying lubricant can be extended.

C-Wiper /RC /RCC



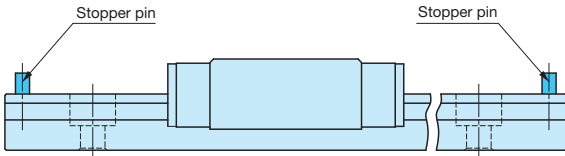
C-Wiper is mounted on the slide unit end to improve dust protection property. In addition, the slide unit with C-Wiper is equipped with inner seal (/UR) and scraper (/Z) together.

- ① /RC Fit C-Wiper to slide unit end nearest to both ends of the track rail. When only one slide unit is used, fit them to both ends of the track rail.
- ② /RCC When two or more slide units are used, fit C-Wiper to both ends of each slide unit.

Special environment seal /RE

The standard end seal and under seal are replaced with seals for special environment that can be used at high temperatures.

Track rail with stopper pins /S

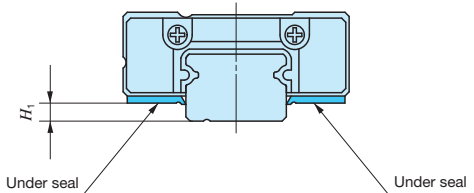


Mount stopper pins to both ends of the track rail as slide unit retainers.

Butt-jointing track rails (Interchangeable specification) /T

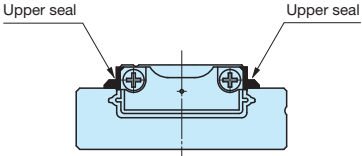
Finish the butted parts at both ends so as to set the interchangeable specification track rail in a linear motion direction. Butt the same interchangeable code for track rails. For non-interchangeable specification, specify butt-jointing track rails "/A".

Under seal ⁽¹⁾ /U

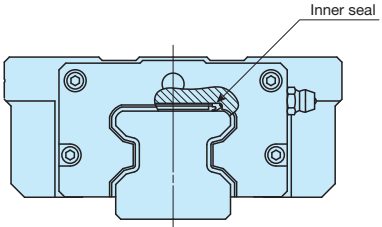


The seal is attached to the bottom of the slide unit to prevent foreign substances from entering from underneath.

Note ⁽¹⁾ For C-Lube Linear Way UL and Linear Way U, attach "upper seal". The seal is attached to the upper end of the slide unit to prevent foreign substances from entering from above.

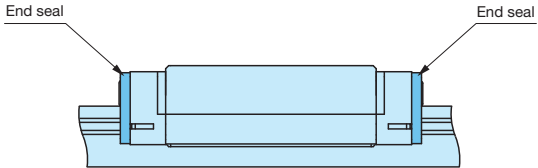


Inner seal /UR



Attach the inner seal to the inside of the slide unit. Inner seal improves dust protection property of the cylindrical roller circulation part against foreign substances from the upper surface of the track rail.

End seal /US



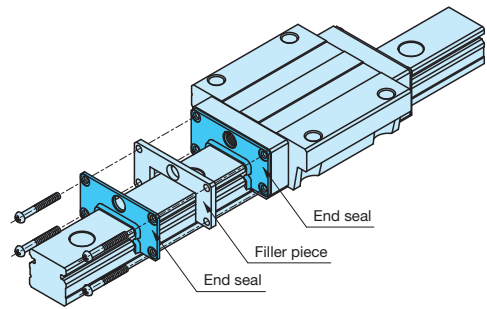
Attach end seals instead of scrapers on both sides of the slide unit in order to improve the dust protection performance.

Double seals (Single unit) /V /VR /VL

Double end seals are mounted to the interchangeable specification slide unit to improve the dust protection property.

- ① /V Apply double seals to both ends of the slide unit.
- ② /VR Apply double seals to a right end surface of the slide unit seen from the  mark of the slide unit.
- ③ /VL Apply double seals to a left end surface of the slide unit seen from the  mark of the slide unit.

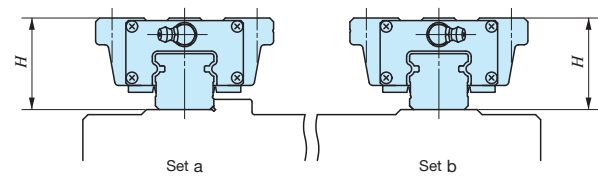
Double seals (Assembled set) /N /VV



Double end seals are mounted to the interchangeable specification assembled set or non-interchangeable specification product's slide unit to improve the dust protection property.

- ① /N Apply double seals to slide unit end nearest to both ends of the track rail. When only one slide unit is used, fit them to both ends of the track rail.
- ② /VV When two or more slide units are used, apply double seals to both ends of each slide unit.

A group of multiple assembled sets /W



Set the variation of H dimensions of the Linear Way and Linear Roller Way of multiple assembled sets on the same flat surface in the standard range. The variation of H dimensions of the multiple assembled sets is the same as the accuracy of one set. Indicate the number of sets after "/W" based on the number of units when specify.

Specified grease /YCG /YCL /YAF /YBR /YNG

The type of pre-packed grease can be changed by the supplemental code.

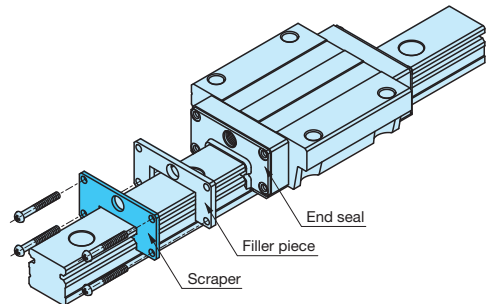
- ① /YCG Low Dust-Generation Grease for Clean Environment CG2 is pre-packed.
- ② /YCL Low Dust-Generation Grease for Clean Environment CGL is pre-packed.
- ③ /YAF Anti-Fretting Corrosion Grease AF2 is pre-packed.
- ④ /YBR MOLYCOTE BR2- Plus Grease [Dow Corning] is pre-packed.
- ⑤ /YNG No grease is pre-packed.

Scraper (Single unit) /Z /ZR /ZL

Mount a metal scraper to the interchangeable specification slide unit. The scraper is non-contact type and effectively eliminate large foreign substances adhering to the track rail.

- ① /Z Mount scrapers to both ends of the slide unit.
- ② /ZR Fit a scraper to a right end surface of the slide unit seen from IKO mark of the slide unit.
- ③ /ZL Fit a scraper to a left end surface of the slide unit seen from IKO mark of the slide unit.

Scraper (Assembled set) /Z /ZZ



Mount a metal scraper to the interchangeable specification assembled set or non-interchangeable specification product's slide unit. The scraper is non-contact type and effectively eliminate large foreign substances adhering to the track rail.

- ① /Z Fit a scraper to slide unit end nearest to both ends of the track rail. When only one slide unit is used, fit them to both ends of the track rail.
- ② /ZZ When two or more slide units are used, fit scrapers to both ends of each slide unit.

Precaution for Use

Operating temperature

The maximum operating temperature for linear motion rolling guide with integrated C-Lube is 80°C. The maximum operating temperature for linear motion rolling guide without integrated C-Lube is 120°C and temperature up to 100°C is allowed for continuous operation. When the temperature exceeds 100°C, contact IKO. When specifying special specification with C-Lube plate (supplemental code "/Q"), utilize it below 80°C.

Multiple slide units used in close proximity

When using multiple slide units in close proximity, greater load may be applied than the calculated value depending on the deviation of slide unit mounting accuracy for the machine or device. In such cases, allowance for greater applied load than the calculated value should be made.

Lateral or upside-down mounting

For lateral or upside-down mounting of the Linear Way E and Linear Way F, specify the special specification (supplemental code "/U") with under seal as necessary to prevent foreign substances from entering into the slide unit.

Operation velocity

Operation velocity limit value of the Linear Way and Linear Roller Way depends on operation conditions such as motion characteristics, applied load, lubrication status, mounting accuracy and environment temperature. Reference values based on actual performance and experienced values as a reference of maximum velocity under typical operating conditions are indicated in Table 19.

Table 19 Reference maximum velocity

Size	Maximum velocity m/min
35	180
45	120
55	100
65	75

Cleaning and removing fat

Never clean up a linear motion rolling guide with integrated C-Lube with organic solvent or white kerosene with property of removing fat.

Lubrication oil supply point for oil lubrication

If the lubrication oil is supplied by a gravity drip system, enough lubrication oil may not be supplied to ways above the supply point, so lubrication path and supply point must be considered. For such applications, contact IKO.

Precaution for Mounting

When mounting multiple assembled sets at the same time

- Interchangeable specification products For interchangeable specification products, assemble a slide unit and a track rail with the same interchangeable code ("S1" or "S2").
- Non-interchangeable specification products Do not change the combination of delivered slide unit and track rail.
- Product including multiple assembled sets For special specification (supplemental code "/W") products with multiple assembled sets, the delivered combination is managed as a group for variation. So do not mix with different group for mounting.

Assembling of slide unit and track rail

When assembling the slide unit on the track rail, correctly fit the grooves of the slide unit and the track rail and move the slide unit softly in parallel direction. Rough handling may result in damaging of seals or dropping of steel balls and cylindrical roller. For product including a dummy rail as a standard accessory, operation of the slide unit to the track rail can be made easier by using the dummy rail. Though the dummy rail is included as an accessory of products indicated in Table 21.1 and Table 21.2, it is also available for other products. If these parts are necessary, please contact IKO.

Mounting accuracy

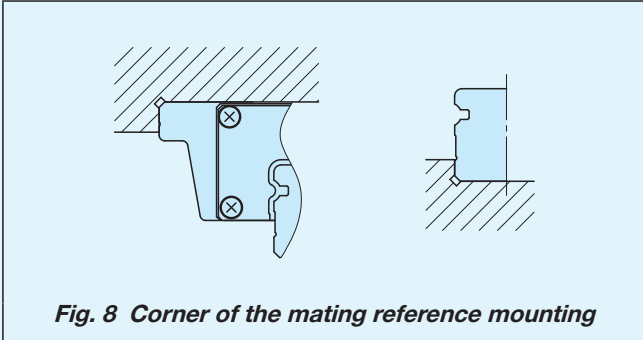
Deviation of accuracy of Linear Way and Linear Roller Way mounting surface or deviation of accuracy in mounting may generate large load over the calculated value. Note that such load could affect the life adversely. It enhances the reliability of Linear Way and Linear Roller Way to ensure high machining accuracy and assembly accuracy depending on operational conditions of the track rail and slide unit such as required motion accuracy and rigidity and to consider mounting structure that can maintain the accuracy and performance. Typical reference values for mounting parallelism between multiple assembled sets used are shown in Table 20.

Table 20 Parallelism between two mounting surfaces unit: μm

Classification	Ordinary (No symbol)	High (H)	Precision (P)	Super precision (SP)	Ultra precision (UP)
Parallelism	30		20	10	6

Shoulder height and corner radius of the reference mounting surface

For the shape of opposite corner of the reference surface, it is recommended to have relieved fillet as indicated in Fig. 8, but you may also use it with providing radius at the corner. For recommended values for the shoulder height and corner radius of the reference mounting surface, see an explanation of each series.



1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

Precaution for Mounting

Table 21.1 Products appended with dummy rail

○: Appended

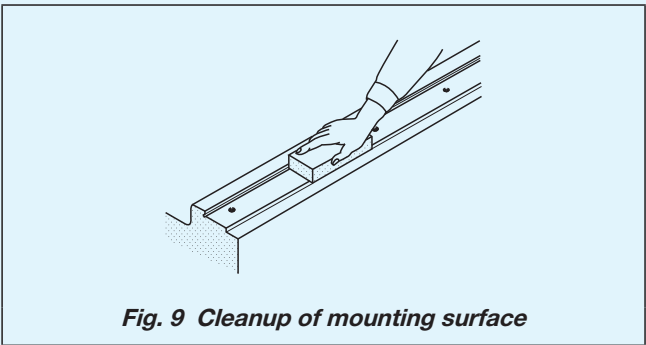
Series name and size		Interchangeable		Non-interchangeable specification
		Single unit	Assembled set	Assembled set
C-Lube Linear Way ML Linear Way L		○	See Table 21.2	See Table 21.2
C-Lube Linear Way MLV		—	—	—
C-Lube Linear Way MV		—	—	—
C-Lube Linear Way ME Linear Way E		○	—	—
C-Lube Linear Way MH Linear Way H	8~12	○	○	○
	15~65	○	—	—
	Extra long	○	○	○
Linear Way F		○	—	—
C-Lube Linear Way MUL Linear Way U	25, 30	—	—	○
	40~86	—	—	—
C-Lube Linear Roller Way Super MX Linear Roller Way Super X	10~30	○	○	○
	35~65	○	—	—
	Extra long	○	○	○
	85, 100	—	—	—
Linear Roller Way X		—	—	—

Table 21.2 Appended dummy rail model number for C-Lube Linear Way ML, C-Lube Linear Way MLV and Linear Way L

C-Lube Linear Way ML		C-Lube Linear Way MLV	Linear Way L	
Standard type	Wide type	Standard type	Standard type	Wide type
—	—	—	LWL 2	LWLF 4
MLC 3	MLFC 6	—	LWLC 3	LWLFC 6
ML 3	MLF 6	—	LWL 3	LWLF 6
MLC 5	MLFC 10	—	LWLC 5…B	LWLFC 10…B
ML 5	MLF 10	—	LWL 5…B	LWLF 10…B
MLC 7	MLFC 14	MLV 7	LWLC 7…B	LWLFC 14…B
ML 7	MLF 14	—	LWL 7…B	LWLF 14…B
MLG 7	MLFG 14	—	LWLG 7…B	LWLFG 14…B
MLC 9	MLFC 18	MLV 9	LWLC 9…B	LWLFC 18…B
ML 9	MLF 18	—	LWL 9…B	LWLF 18…B
MLG 9	MLFG 18	—	LWLG 9…B	LWLFG 18…B
MLL 9	—	—	LWLG 12…B	LWLFG 24…B
MLG 12	MLFG 24	—	LWLG 15…B	LWLFG 30…B
MLL 12	—	—	LWLG 20…B	LWLFG 42…B
MLG 15	MLFG 30	—	LWLG 25…B	—
MLL 15	—	—	—	—
MLG 20	MLFG 42	—	—	—
MLG 25	—	—	—	—

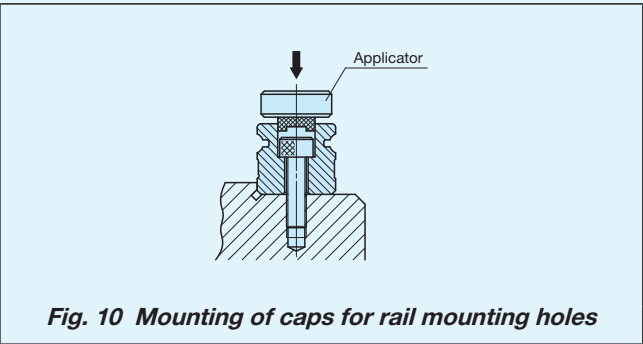
Cleanup of mounting surface

Remove burrs and blemishes by using oil-stone, etc. and wipe off rust prevention oil and dust with clean cloth from mounting surface and reference mounting surface of the machine or device to which the Linear Way or Linear Roller Way are mounted.



Mounting of caps for rail mounting holes

When mounting the special specification caps for rail mounting holes (supplemental code "/F") on the track rail, use a flat applicator and stamp it by bits until it becomes plane with the track rail upper surface.



Tightening torque for fixing screw

Typical fixing screw tightening torque to mount the Linear Way and Linear Roller Way is indicated in Table 22. When vibration and shock of the machine or device are large, fluctuating load is large, or moment load is applied, fix it by using the torque 1.2 to 1.5 times larger than the value indicated as necessary.

If the mating member material is cast iron or aluminum alloy, reduce the tightening torque depending on the strength characteristics of the mating member material.

For details, see an explanation of each series.

Though the track rail mounting bolts are appended as an accessory of products indicated in Table 23, it is also available for other products. If these parts are necessary, please contact **IKO**.

Table 22 Tightening torque for fixing screw

Bolt size	Tightening torque N · m			
	High carbon steel-made screw (Strength division 8.8)	High carbon steel-made screw (Strength division 10.9)	High carbon steel-made screw (Strength division 12.9)	Stainless steel-made screw (Property division A2-70)
M 1 ×0.25	—	—	—	0.04
M 1.4×0.3	—	—	—	0.10
M 1.6×0.35	—	—	—	0.15
M 2 ×0.4	—	—	—	0.31
M 2.3×0.4	—	—	—	0.49
M 2.5×0.45	—	—	—	0.62
M 2.6×0.45	—	—	—	0.70
M 3 ×0.5	1.3	—	1.8	1.1
M 4 ×0.7	2.9	—	4.1	2.5
M 5 ×0.8	5.7	—	8.0	5.0
M 6 ×1	—	—	13.6	8.5
M 8 ×1.25	—	—	32.7	20.4
M10 ×1.5	—	—	63.9	—
M12 ×1.75	—	—	110	—
M14 ×2	—	—	175	—
M16 ×2	—	—	268	—
M20 ×2.5	—	—	522	—
M24 ×3	—	749	—	—
M30 ×3.5	—	1 490	—	—

Table 23 Specifications of appended track rail mounting bolts

Series			Specifications of appended bolts		
	Size	Material type	Type	Material	Class
C-Lube Linear Way ML Standard type ⁽¹⁾ Linear Way L Standard type ⁽¹⁾	1~ 3 ⁽²⁾	Stainless steel made	JCIS 10-70 Cross-recessed pan head screw for precision equipment	Stainless steel made	—
	5	Stainless steel made	JCIS 10-70 Cross-recessed pan head screw for precision equipment	Stainless steel made	—
	7~ 25	Stainless steel made	JIS B 1176 Hexagon socket head bolt	Stainless steel made	Property division A2-70
	9~ 20	High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 8.8
C-Lube Linear Way ML Wide type ⁽¹⁾ Linear Way L Wide type ⁽¹⁾	4~ 10	Stainless steel made	JCIS 10-70 Cross-recessed pan head screw for precision equipment	Stainless steel made	—
	14~ 42	Stainless steel made	JIS B 1176 Hexagon socket head bolt	Stainless steel made	Property division A2-70
	18~ 42	High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 8.8
C-Lube Linear Way MLV		Stainless steel made	JIS B 1176 Hexagon socket head bolt	Stainless steel made	Property division A2-70
C-Lube Linear Way MV ⁽³⁾		High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 12.9
C-Lube Linear Way ME ⁽³⁾ Linear Way E ⁽³⁾		Stainless steel made	JIS B 1176 Hexagon socket head bolt	Stainless steel made	Property division A2-70
		High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 12.9
C-Lube Linear Way MH ⁽⁴⁾ Linear Way H ⁽⁵⁾	8~ 30	Stainless steel made	JIS B 1176 Hexagon socket head bolt	Stainless steel made	Property division A2-70
	12	High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 8.8
	15~ 65	High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 12.9
Linear Way F		Stainless steel made	JIS B 1176 Hexagon socket head bolt	Stainless steel made	Property division A2-70
		High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 12.9
C-Lube Linear Way MUL ⁽³⁾	25	Stainless steel made	JCIS 10-70 Cross-recessed pan head screw for precision equipment	Stainless steel made	—
	30	Stainless steel made	JIS B 1176 Hexagon socket head bolt	Stainless steel made	Property division A2-70
Linear Way U ⁽³⁾	40~ 86	High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 12.9
C-Lube Linear Roller Way Super MX ⁽⁴⁾ Linear Roller Way Super X	10~ 65	Stainless steel made	JIS B 1176 Hexagon socket head bolt	Stainless steel made	Property division A2-70
		High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 12.9
	85~100	High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 10.9
Linear Roller Way X	25~ 55	High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 12.9
	75	High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 10.9
Linear Way LM ⁽⁶⁾		Stainless steel made	JIS B 1176 Hexagon socket head bolt	Stainless steel made	Property division A2-70
Linear Way M ⁽⁷⁾ Linear Roller Way M ⁽⁷⁾		High carbon steel made	JIS B 1176 Hexagon socket head bolt	High carbon steel made	Strength division 12.9

Notes ⁽¹⁾ The bolts are not appended for tapped rail specification.

⁽²⁾ The bolts are not appended. Specifications in the table are the ones prepared by **IKO**.

⁽³⁾ The bolts are not appended. Specifications in the table are the ones when special specification "/MA" (with track rail mounting bolts) is specified.

⁽⁴⁾ The bolts are not appended in an assembled set. Specifications in the table are the ones when special specification "/MA" (with track rail mounting bolts) is specified.

⁽⁵⁾ The bolts are not appended in LWH···MU.

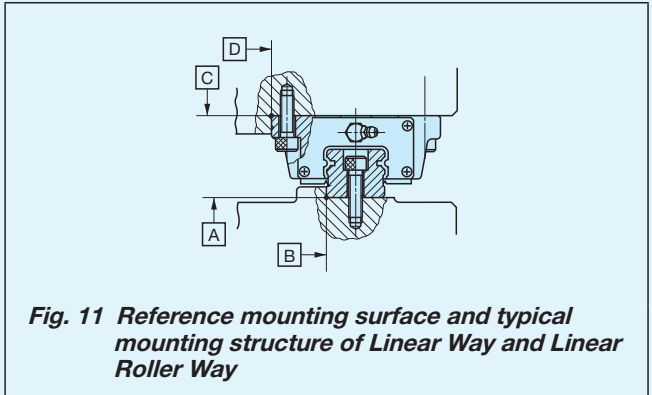
⁽⁶⁾ Slide member mounting bolts are not appended.

⁽⁷⁾ Slide member mounting bolts are also appended.

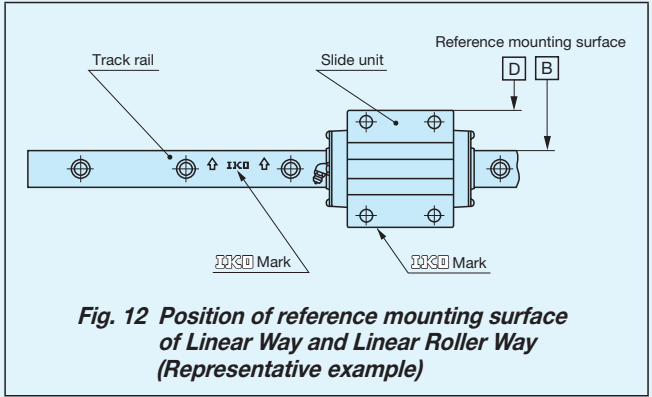
Mounting surface, reference mounting surface and typical mounting structure

When mounting Linear Way and Linear Roller Way, properly align the reference mounting surface B and D of the track rail and slide unit with the reference mounting surface of the table and bed and fix them. (See Fig. 11)

The reference mounting surfaces B and D and mounting surfaces A and C are precisely ground. Machining the mounting surface of the table and bed, such as machine or device, to high accuracy and mounting them properly will ensure stable linear motion with high accuracy.



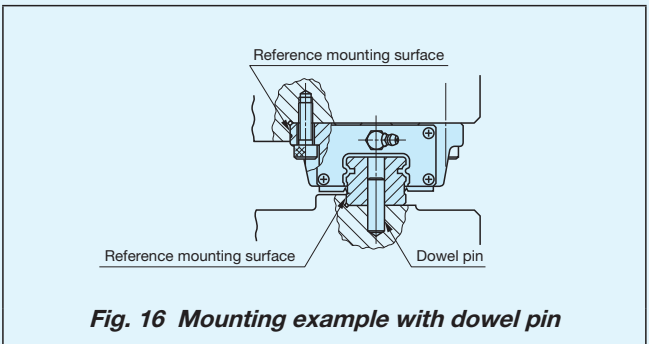
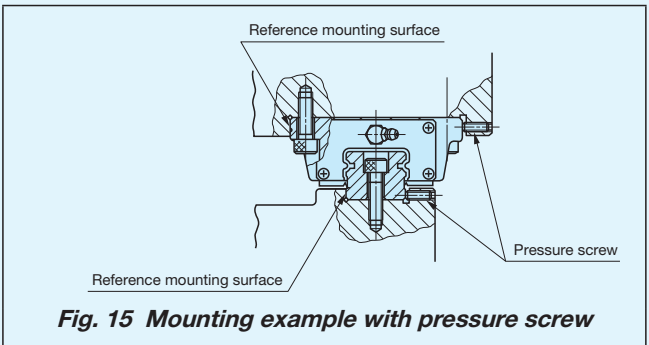
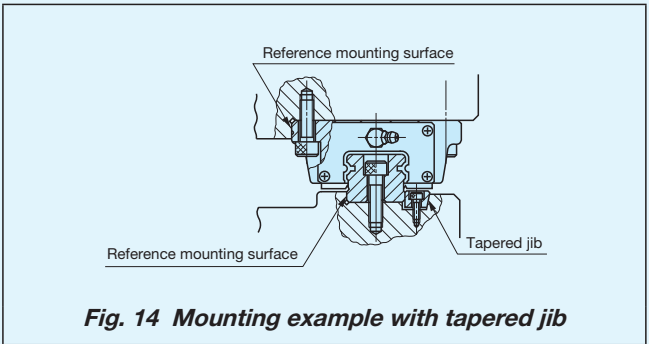
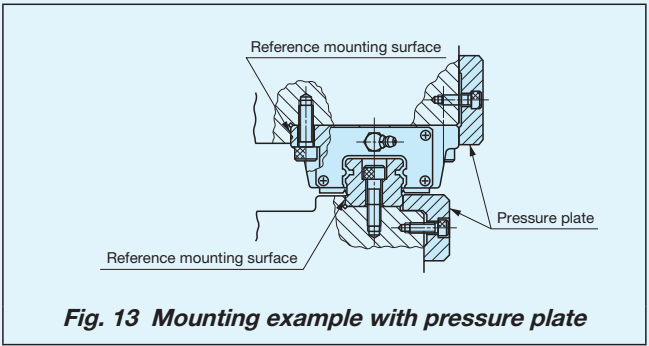
Reference mounting surface of the slide unit is the opposite side of the **IKO** mark. The track rail reference mounting surface is identified by locating the **IKO** mark on the top surface of the track rail. It is the side surface above the mark (in the direction of the arrow). (See Fig. 12.)



Load direction and mounting structure

When lateral load, alternate load, or fluctuating load is applied onto the Linear Way or Linear Roller Way, securely fix the ends of slide unit and track rail as indicated in the Fig. 13 and Fig. 14.

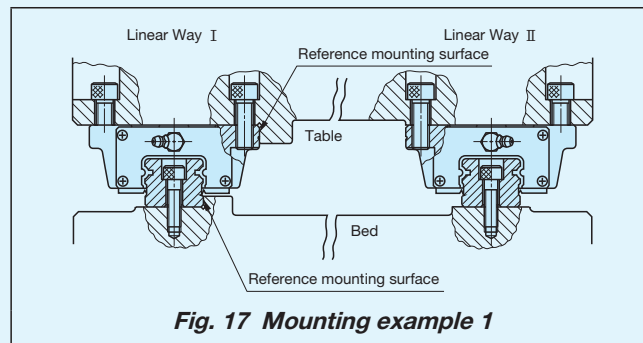
When the load is small or operational conditions are not harsh, mounting methods indicated in Fig. 15 and Fig. 16 may be used.



Mounting Examples

Typical procedures to mount Linear Way and Linear Roller Way are described in Examples 1 to 4 using a Linear Way as a representative case.

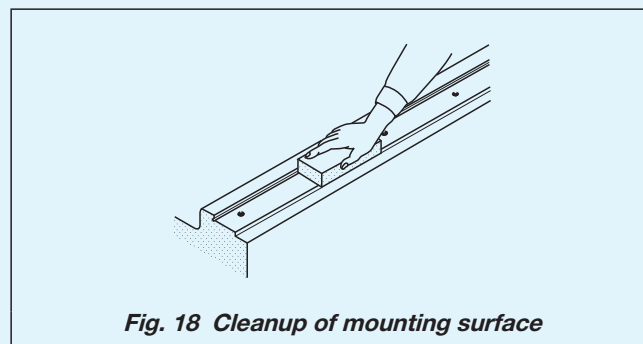
Example 1. Typical operation



For typical application without shock, reference mounting surface is prepared on each bed and table on the reference side. The mounting procedures are as follows. (See Fig. 17)

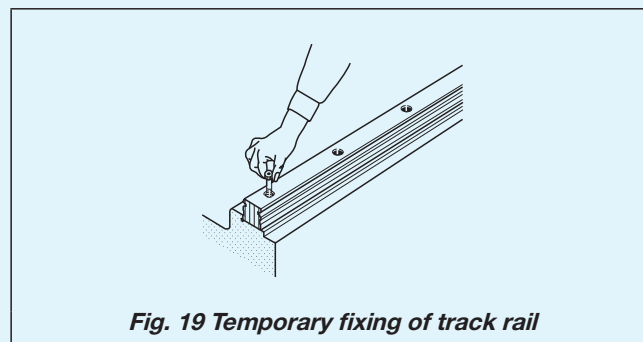
① Cleanup of mounting surface and reference mounting surface

- Remove burrs and blemishes by using oil-stone, etc. from reference mounting surface and mounting surface of the machine or the device to which Linear Way is mounted and wipe off with clean cloth. (see Fig. 18)
- Wipe off rust prevention oil and dust on the reference mounting surface and the mounting surface of the Linear Way with clean cloth.



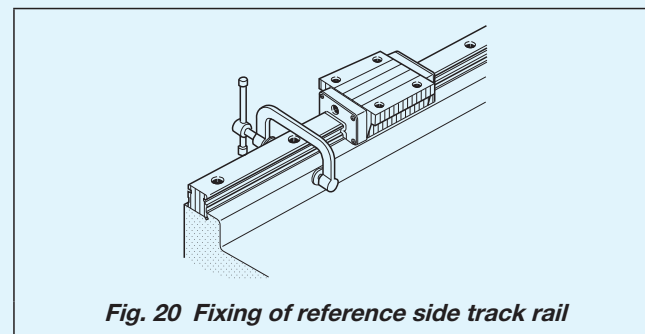
② Temporary fixing of Linear Way I and II track rails

- Align and temporarily fix them with reference mounting surface of each Linear Way track rail. (See Fig. 19)
- At this point, ensure that the fixing bolt does not interfere with the mounting hole.
- Fix the Linear Way II track rail to the bed.



③ Fixing of Linear Way I track rail

- Use small type vise or the like to stick track rail reference mounting surface to the reference mounting surface of the bed and tighten the fixing bolt at the same position. Repeat this method from one end to fix the track rail in order. (See Fig. 20)
- Linear Way II track rail should be left temporarily fixed.



④ Temporary fixing of Linear Way I and II slide units

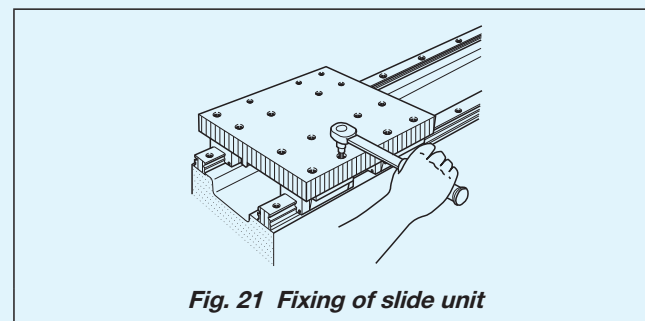
- Align the Linear Way with the mounting position of the table and load the table gently.
- Temporarily fix the Linear Way I and II slide units to the table.

⑤ Fixing of Linear Way I slide unit

- Align the reference mounting surface of the Linear Way I slide unit with the reference mounting surface of the table correctly and fix them.

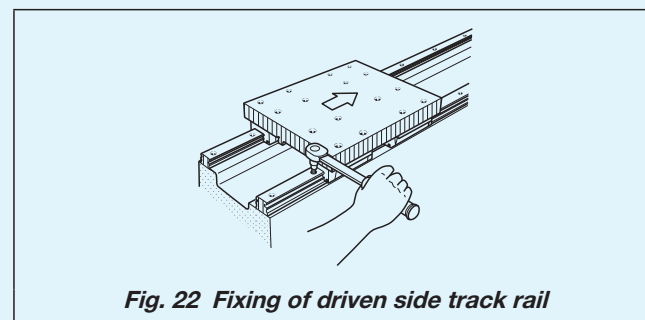
⑥ Fixing of Linear Way II slide unit

- Fix one of the Linear Way II slide units in a motion direction correctly and leave the other slide units temporarily fixed. (See Fig. 21)



⑦ Fixing of Linear Way II track rail

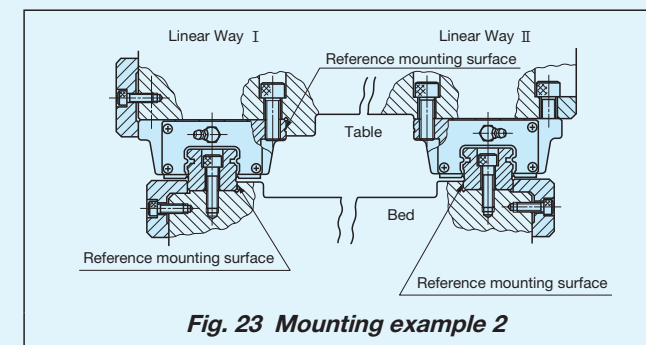
- Move the table and fix the Linear Way II track rail ensuring smooth motion status. At this point, tighten each fixing bolt immediately after the fixed slide unit of the Linear Way II passes on each of it. Repeat this method from one end to fix the track rail in order. (See Fig. 22)



⑧ Fixing of Linear Way II slide unit

- Fix the rest of the Linear Way II slide units.

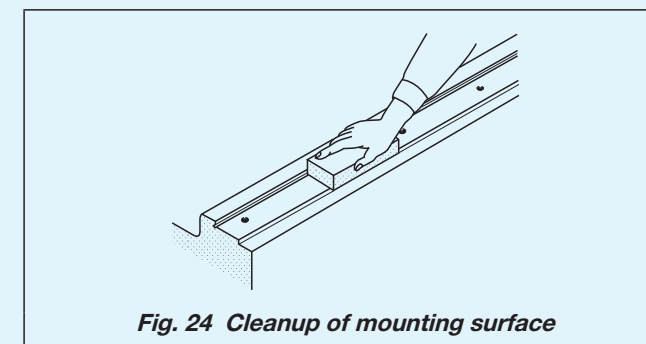
Example 2. Operation for linear motion with accuracy and rigidity



If accuracy and rigidity of linear motion are required, prepare two reference mounting surfaces on the bed and one reference mounting surface on the table. The mounting procedures are as follows. (See Fig. 23)

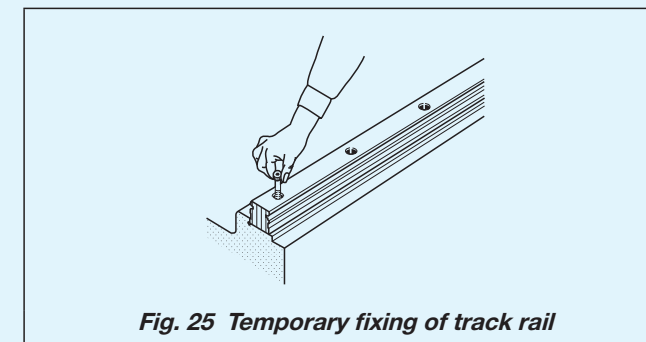
① Cleanup of mounting surface and reference mounting surface

- Remove burrs and blemishes by using oil-stone, etc. from reference mounting surface and mounting surface of the machine or the device to which Linear Way is mounted and wipe off with clean cloth. (see Fig. 24)
- Wipe off rust prevention oil and dust on the reference mounting surface and the mounting surface of the Linear Way with clean cloth.



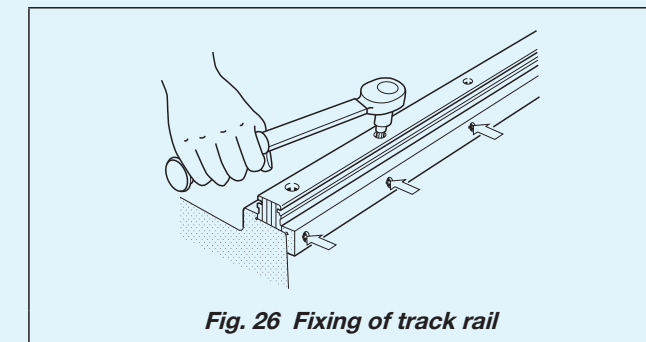
② Temporary fixing of Linear Way I and II track rails

- Align and temporarily fix them with reference mounting surface of each Linear Way track rail. (See Fig. 25)
- At this point, ensure that the fixing bolt does not interfere with the mounting hole.



③ Fixing of Linear Way I and II track rails

- Stick the track rail reference mounting surface of the Linear Way I to the reference mounting surface of the bed with pressure plate or pressure screws and tighten the track rail fixing bolt at the same position. Repeat this method from one end to fix the track rail in order. (See Fig. 26)



④ Temporary fixing of Linear Way I and II slide units

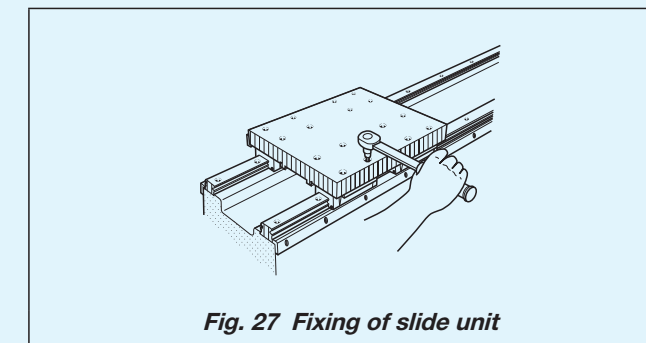
- Align the slide unit with the mounting position of the table and load the table gently. Temporarily fix the Linear Way I and II slide units to the table.

⑤ Fixing of Linear Way I slide unit

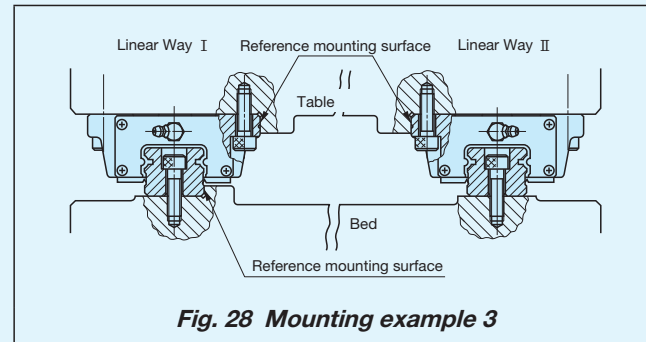
- Align the reference mounting surface of the Linear Way I slide unit with the reference mounting surface of the table correctly and fix them with pressure plate or pressure screws.

⑥ Fixing of Linear Way II slide unit

- Move the table ensuring smooth motion status, and fix the Linear Way II slide unit. (See Fig. 27)



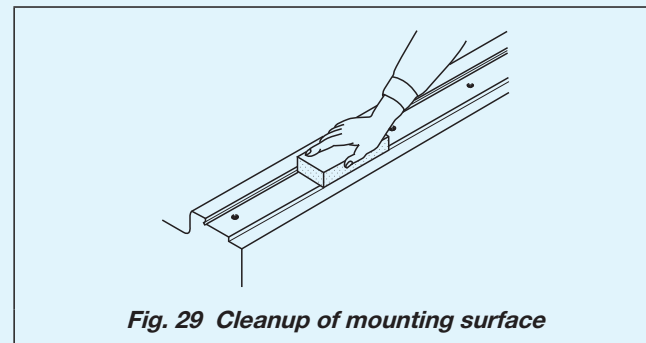
Example 3 Operation in case the slide unit is fixed separated from the track rail



If it cannot be fixed securely with the table loaded, prepare one reference mounting surface on the bed and two reference mounting surfaces on the table. The mounting procedures are as follows. (See Fig. 28)

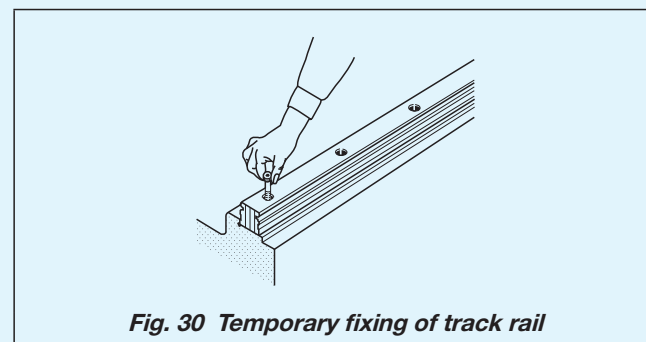
① Cleanup of mounting surface and reference mounting surface

- Remove burrs and blemishes by using oil-stone, etc. from reference mounting surface and mounting surface of the machine or the device to which Linear Way is mounted and wipe off with clean cloth. (see Fig. 29)
- Wipe off rust prevention oil and dust on the reference mounting surface and the mounting surface of the Linear Way with clean cloth.



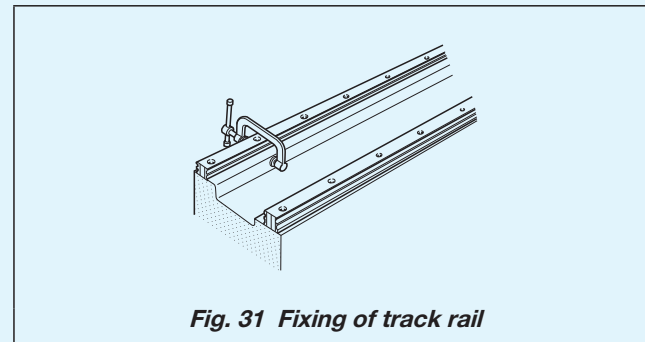
② Temporary fixing of Linear Way I and II track rails

- Align and temporarily fix them with reference mounting surface of each Linear Way track rail. (See Fig. 30)
- At this point, ensure that the fixing bolt does not interfere with the mounting hole.



③ Fixing of Linear Way I track rail

- Use small type vise or the like to stick track rail reference mounting surface to the reference mounting surface of the bed and tighten the fixing bolt at the same position. Repeat this method from one end to fix the track rail in order. (See Fig. 31)
- Linear Way II track rail should be left temporarily fixed.

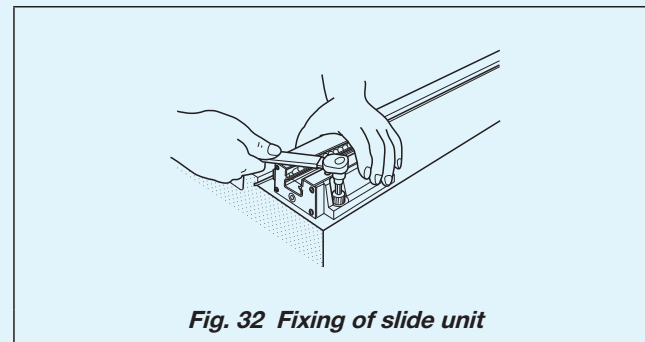


④ Separation of track rail and slide unit

- After checking the combination and positions of Linear Way I and II track rails and slide units, separate each slide unit from the track rail.

⑤ Fixing of Linear Way I and II slide units

- Align with the reference mounting surface of the Linear Way I and II slide units correctly, and fix them. (See Fig. 32)



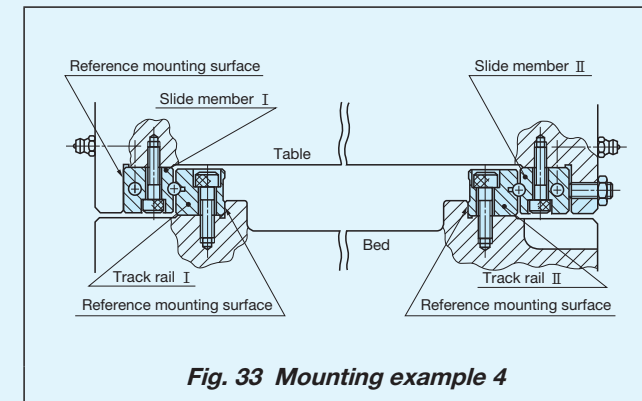
⑥ Setting of track rail and slide unit

- Insert and assemble the slide unit fixed to the table slowly with care while aligning it with the track rail fixed and temporarily fixed to the bed to maintain parallelism.

⑦ Fixing of Linear Way II track rail

- Move the table and fix the Linear Way II track rail ensuring smooth motion status. At this point, tighten each fixing bolt immediately after the fixed slide unit of the Linear Way II passes on each of it. Repeat this method from one end to fix the track rail in order.

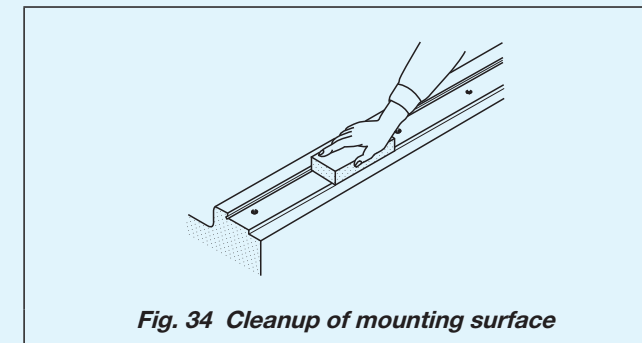
Example 4. Operation of Linear Way Module



For the Linear Way Module, normally 2 sets are used in parallel as indicated in Fig. 33. For the mounting, typically follow the procedure below (see Fig. 33).

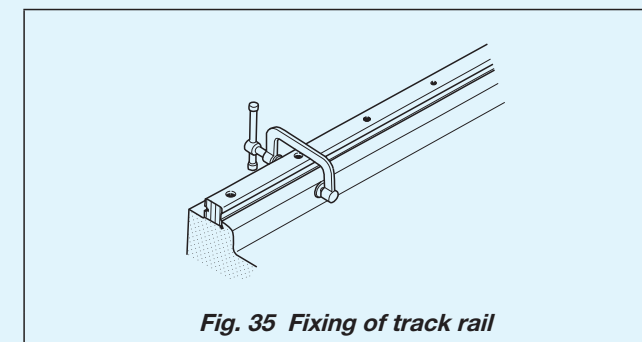
① Cleanup of mounting surface and reference mounting surface

- Remove burrs and blemishes by using oil-stone, etc. from reference mounting surface and mounting surface of the machine or the device to which Linear Way Module is mounted and wipe off with clean cloth (see Fig. 34).
- Wipe off rust prevention oil and dust on the reference mounting surface and the mounting surface of the Linear Way Module with clean cloth.



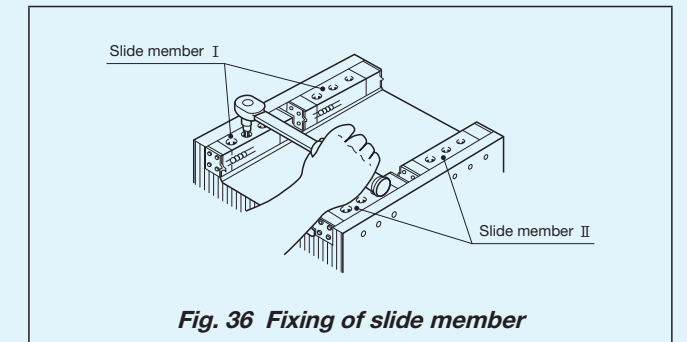
② Fixing of track rail

- Align the reference mounting surfaces of track rails I and II with the reference mounting surfaces of the bed correctly, stick them by using small type vise, and tighten the fixing bolts at the same position (see Fig. 35).



③ Fixing the slide member

- Align the reference mounting surface of the slide member I with the reference mounting surface of the table correctly, tighten the fixing bolt to fix them, and temporarily fix the slide member II (see Fig. 36).

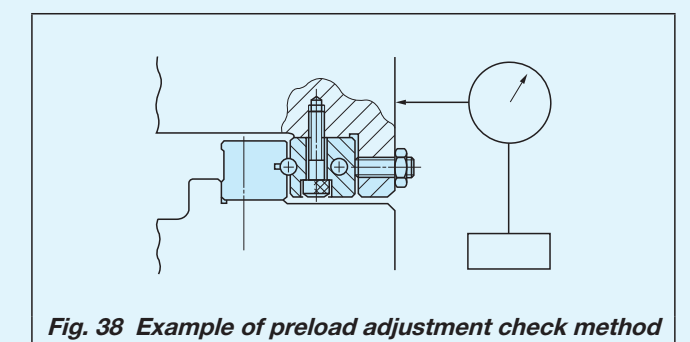
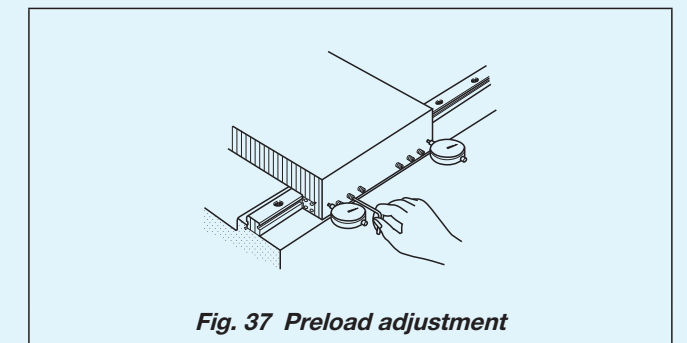


④ Setting of table and bed

- Insert and assemble the slide member fixed to the table slowly with care while aligning it with the track rail fixed to the bed to maintain parallelism.

⑤ Fixing the slide member II

- As indicated in Fig. 37, tighten the preload adjusting screw at the center first and then all the rest preload adjusting screws in order while measuring the clearance by using the dial gauge.
- The position where the dial gauge deflection stops after moving the table to right and left indicates zero preload or slight preload state.
- After preload adjustment, tighten the fixing bolt to fix them.



Mounting of reference side track rail

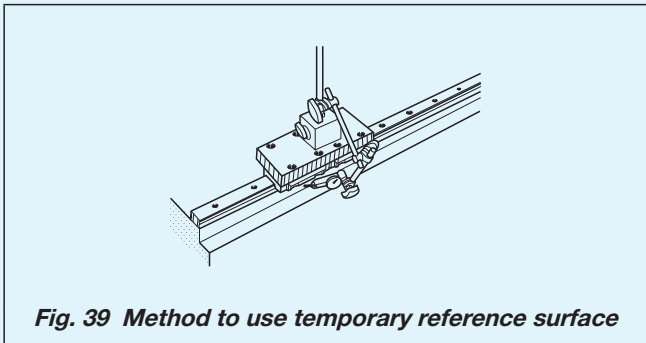
Mounting methods of reference side track rail are indicated below. Select a method suitable for the specifications of your machine or device.

① Method to use reference mounting surface

- Stick track rail reference mounting surface to the reference mounting surface of the bed by using a pressure plate or small type vise, and tighten the fixing bolt at the same position. Repeat this method from one end to fix the track rail in order.

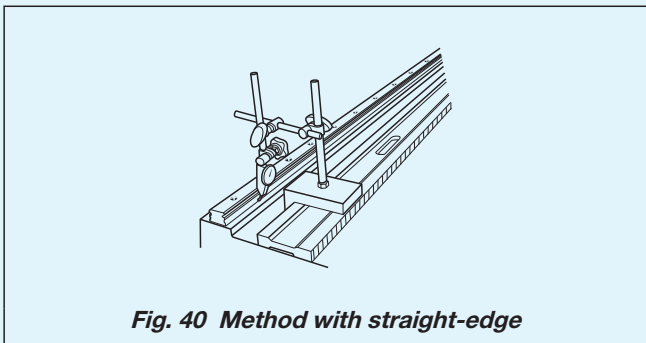
② Method to use temporary reference surface

- Prepare temporary reference surface around the mounting surface of the bed, temporarily fix the track rail, fix the measurement stand on the upper surface of the slide unit as indicated in Fig. 39, place an indicator onto the temporary reference surface, and fix them from one end of the track rail in order while maintaining straightness.



③ Method with straight-edge

- After temporary fixing of the track rail, apply an indicator to the reference mounting surface of the track rail as indicated in Fig. 40 and fix them from one end of the track rail in order referring to the straight-edge while maintaining straightness.



Mounting of driven side track rail

Mounting methods of driven side track rail are indicated below. Select a method suitable for the specifications of your machine or device.

① Method to use reference mounting surface

- Stick track rail reference mounting surface to the reference mounting surface of the bed by using a pressure plate or small type vise, and tighten the fixing bolt at the same position. Repeat this method from one end to fix the track rail in order.

② Method to follow the reference side track rail

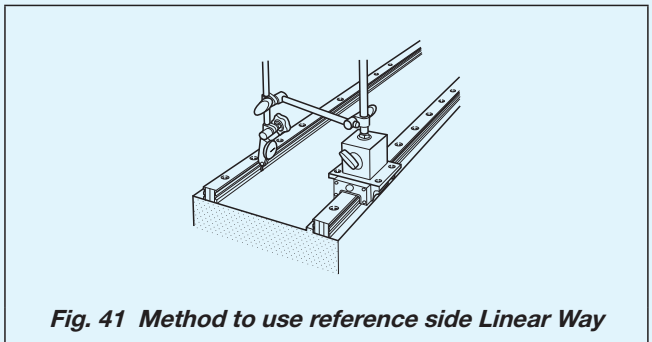
- Correctly mount the reference side track rail and one of the driven slide units in motion direction, temporarily fix the rest of slide units and track rails, and fix them from one end of the driven side track rail in order ensuring smooth motion status.

③ Method with straight-edge

- After temporary fixing of the track rail, apply an indicator to the reference mounting surface of the track rail as indicated in Fig. 40 and fix them from one end of the track rail in order referring to the straight-edge while maintaining straightness.

④ Method to use reference side Linear Way

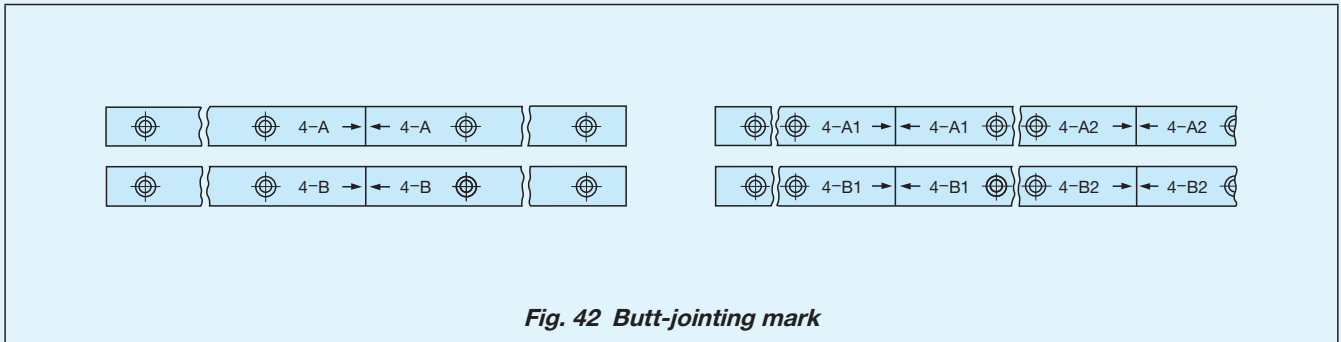
- Fix a measurement stand onto the upper surface of the reference side slide unit as indicated in Fig. 41, place an indicator onto the reference mounting surface of the driven side track rail, and fix them from one end in order while maintaining parallelism.



Mounting procedures when track rails are butt-jointed

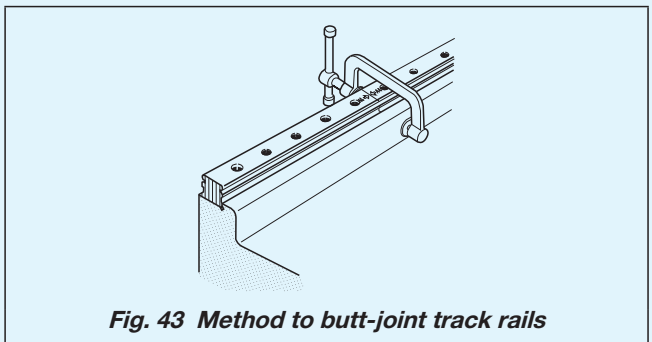
When multiple track rails are butt-jointed, it is necessary to specify special specification butted track rails (non-interchangeable specification, supplemental code "/A") or butt-jointing track rails (interchangeable specification, supplemental code "/T").

Butt-jointing track rails have a butt-jointing mark on the track rail end surface as indicated in Fig. 42. Typical method to butt-joint the track rails is as follows.



- ① Align the butt-jointing mark on the track rail end surface and temporarily fix it. Since butt-jointing track rails are interchangeable, no butt-jointing position is specified.

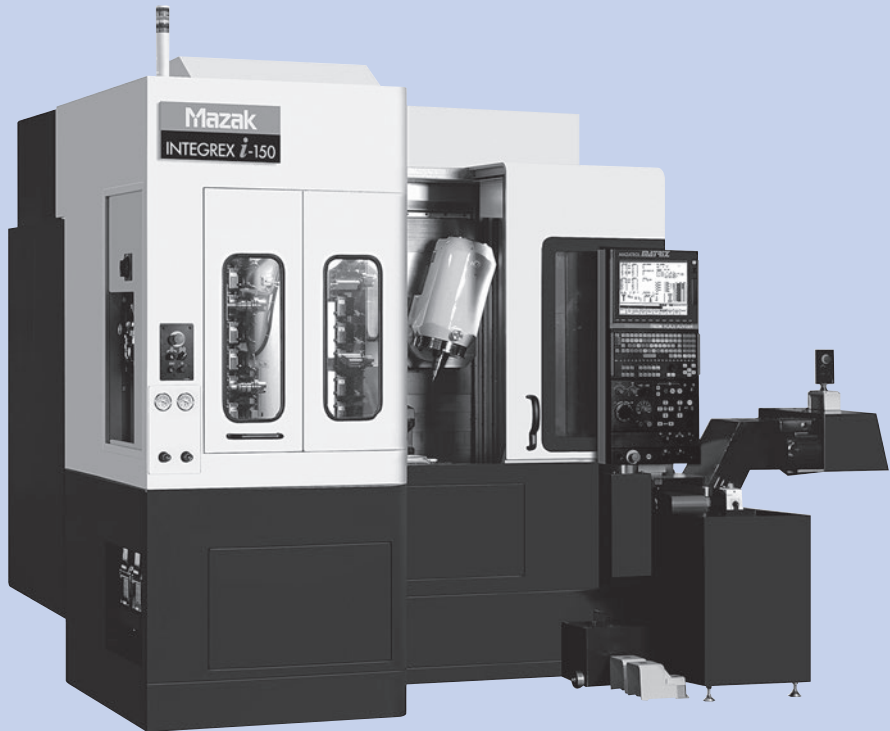
- ② Correctly align the reference mounting surface of the track rail with that of the bed in order. At this point, use a small type vise or the like to stick the reference mounting surfaces of the bed and track rail together so as to eliminate any step at the joint part of the track rail. (See Fig. 43)



Introduction of Application Examples

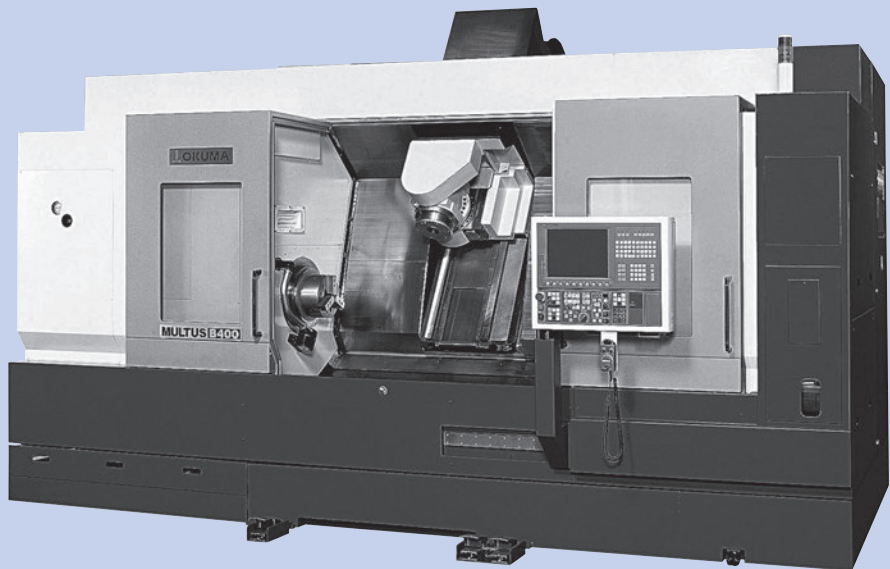
Complex machining center

LRX



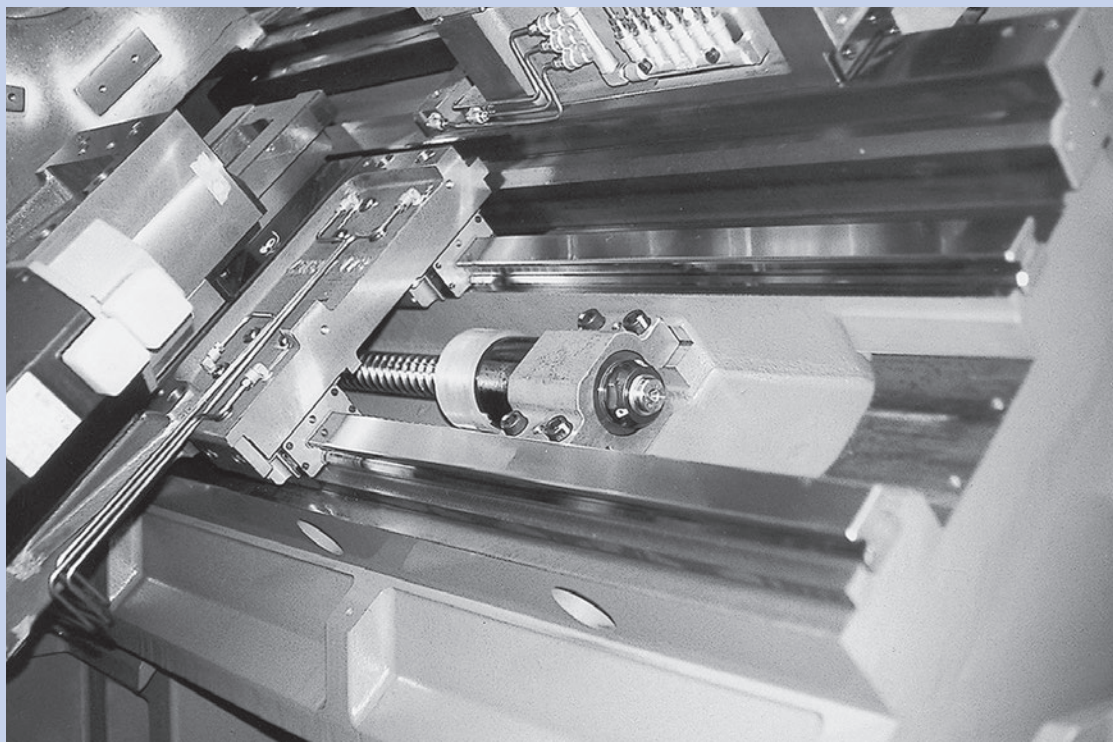
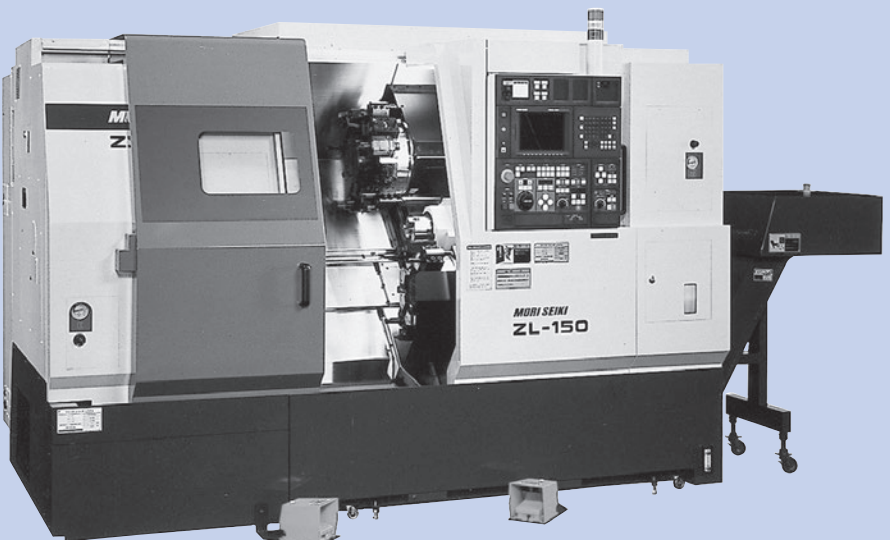
Lateral type complex machining center

LRX



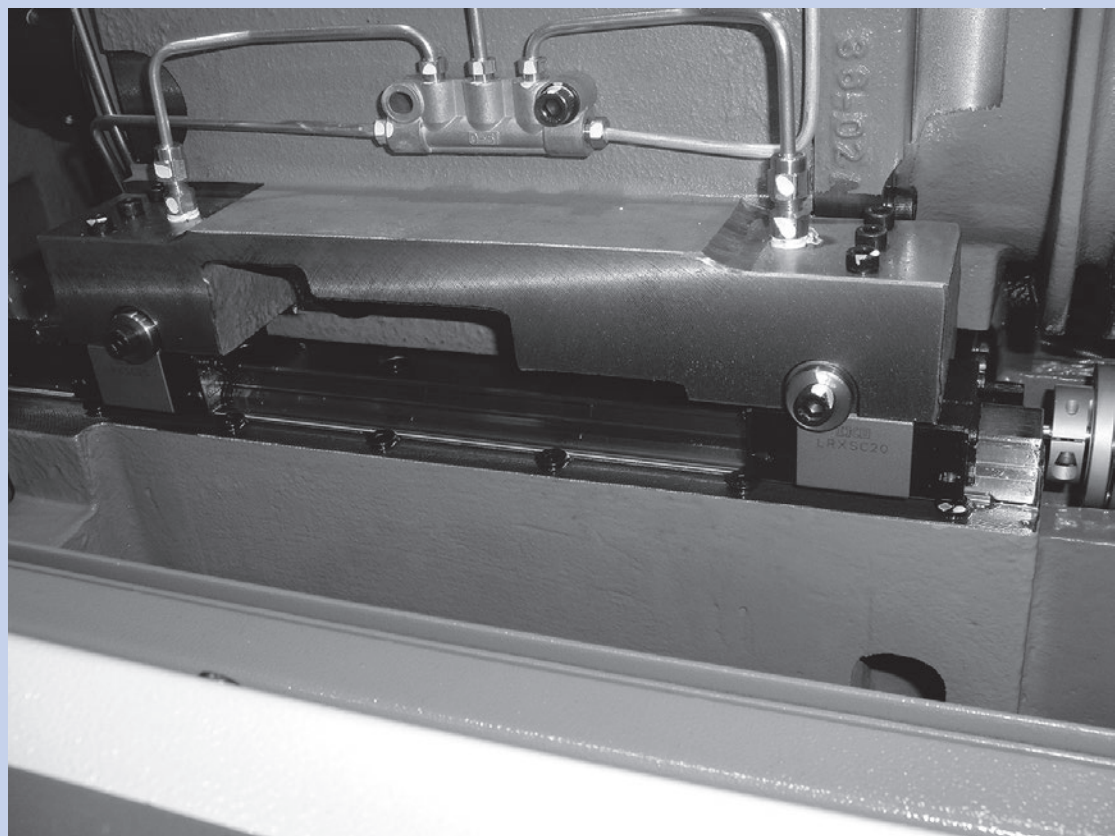
Four-axis control CNC lathe

LRX



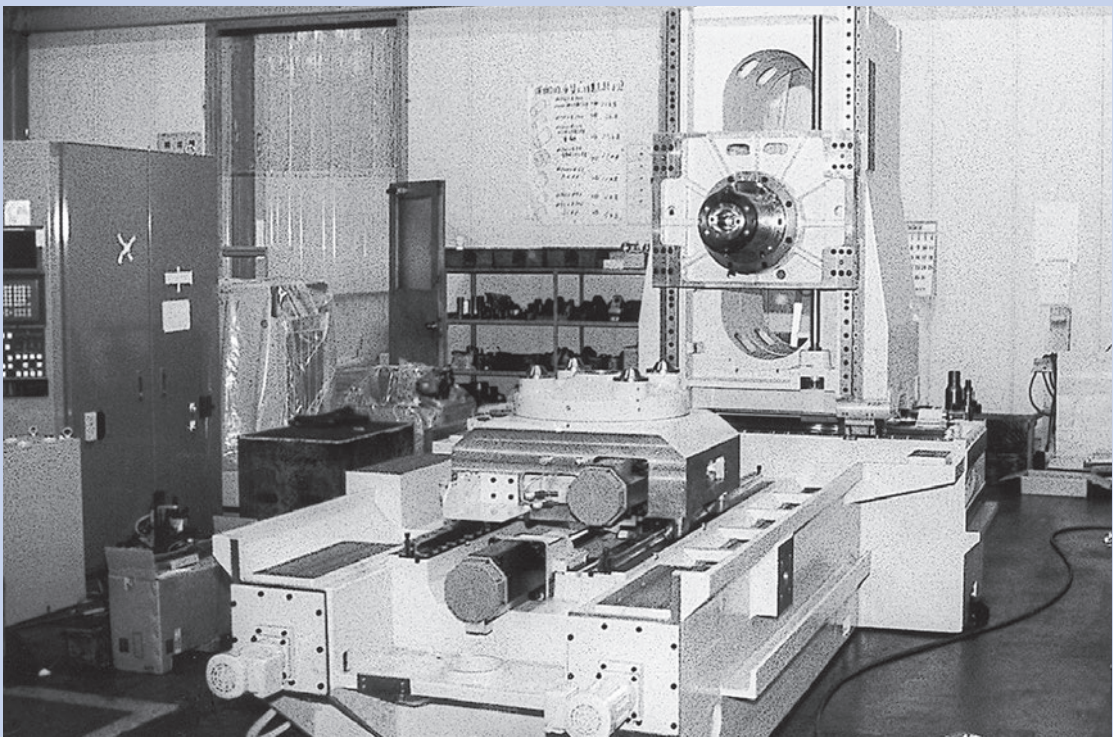
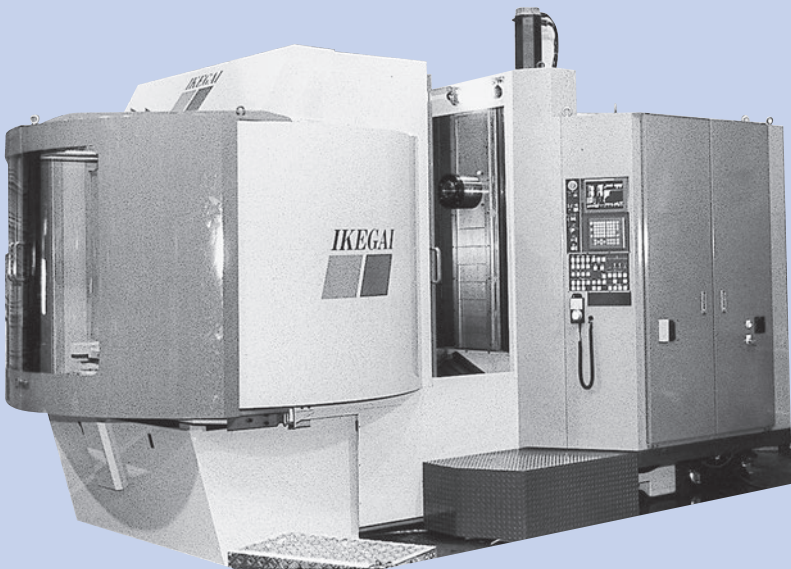
CNC compact type automatic lathe

LRXS · LRXSC



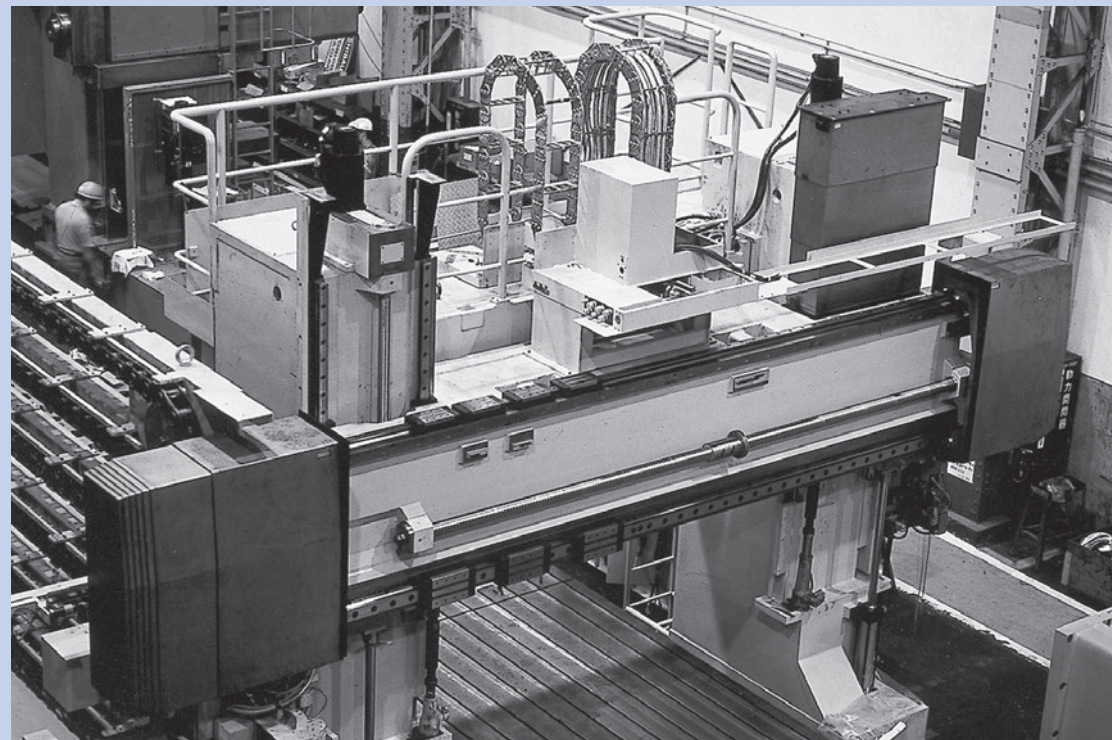
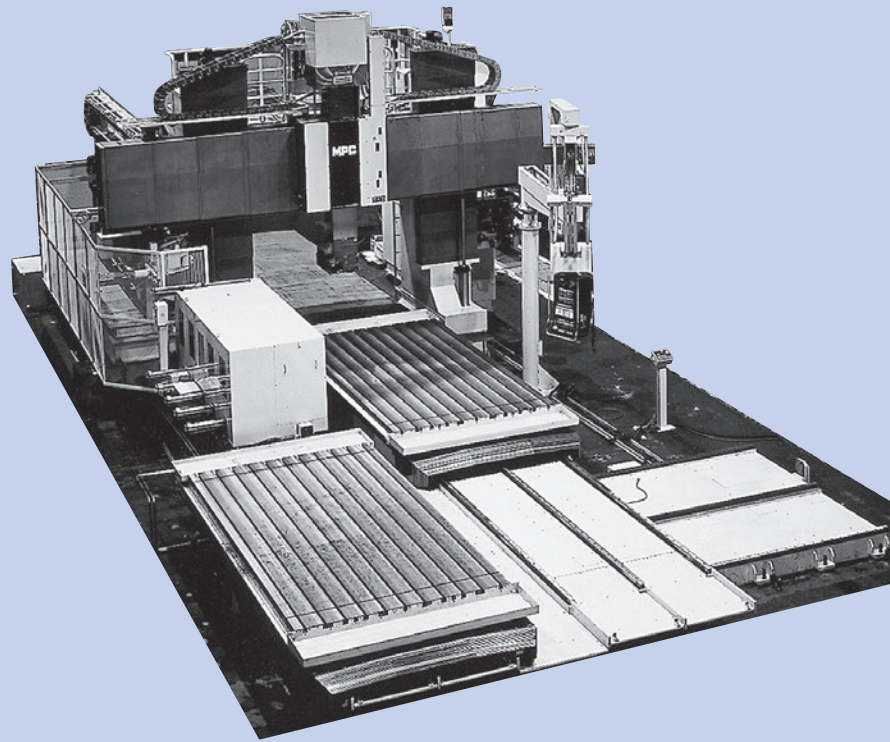
Lateral type machining center

LRX · LRXDG



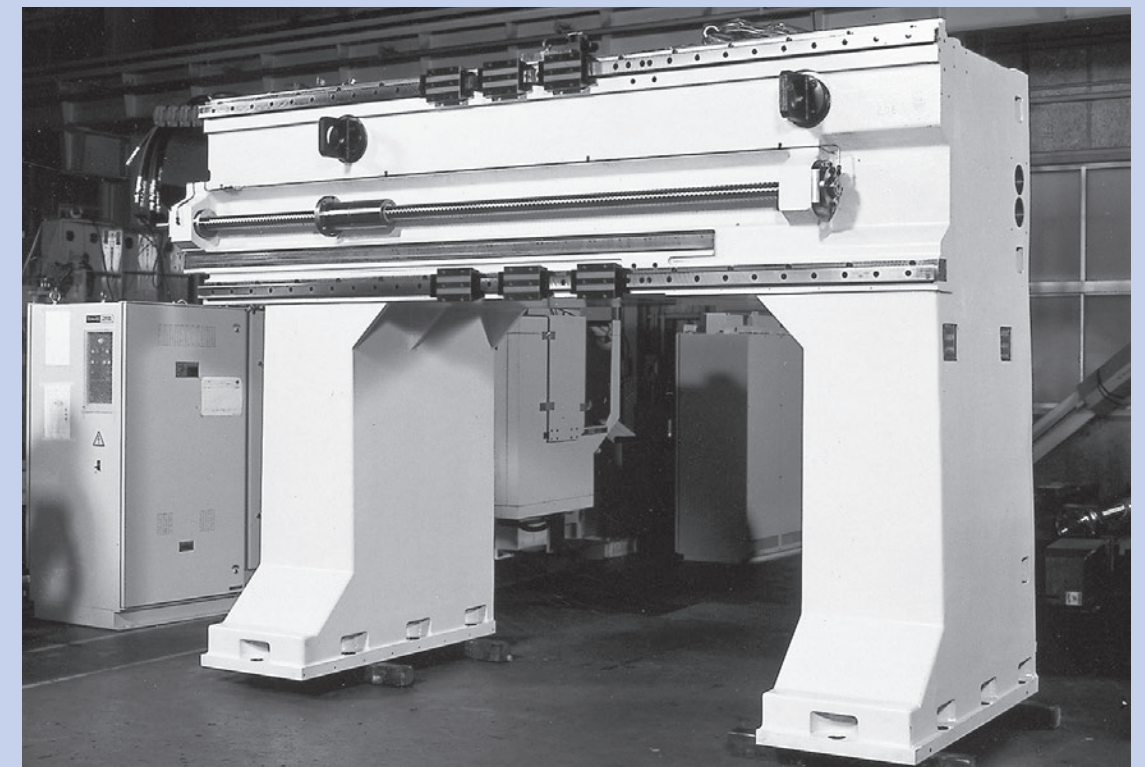
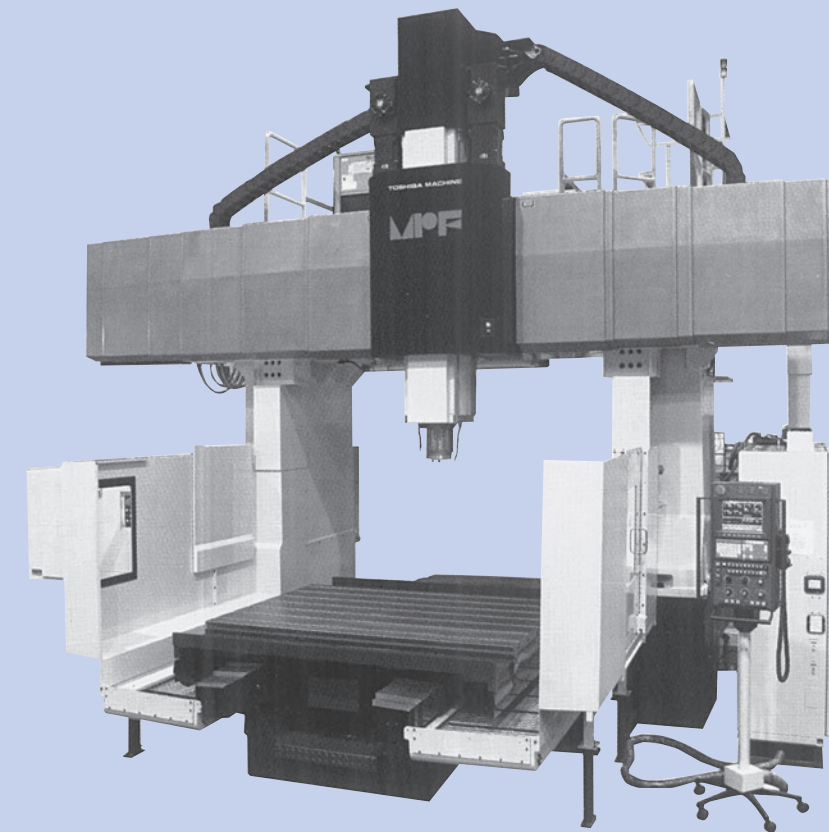
Gantry type machining center

LWHG



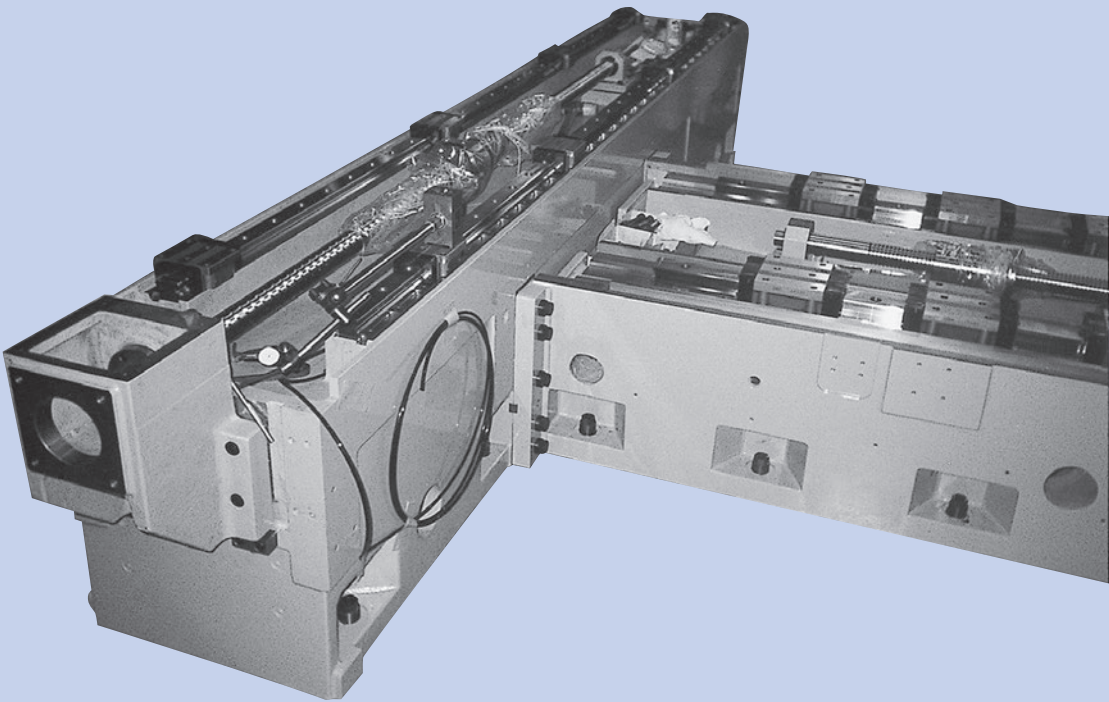
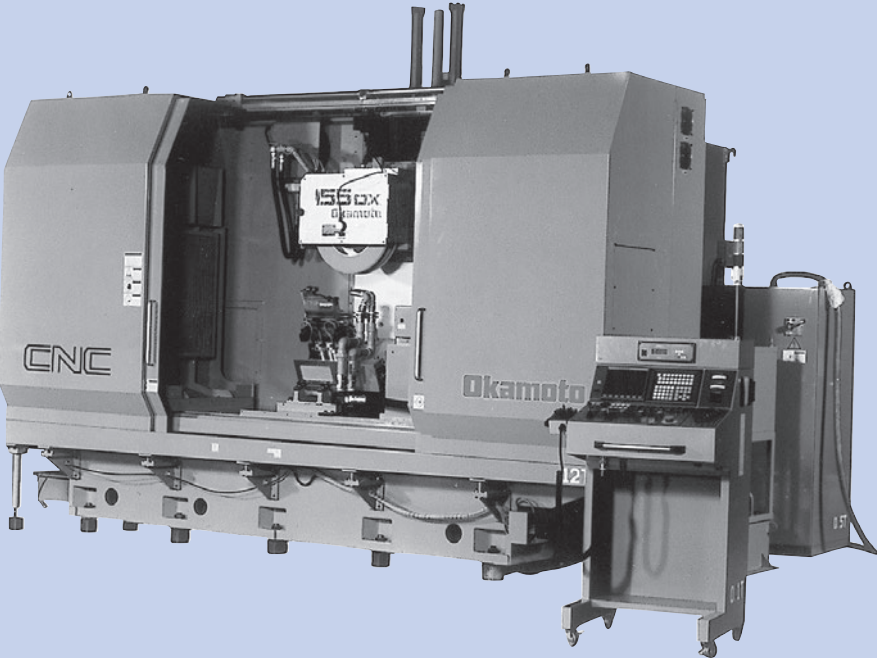
Gantry type machining center

MXG · MXDG



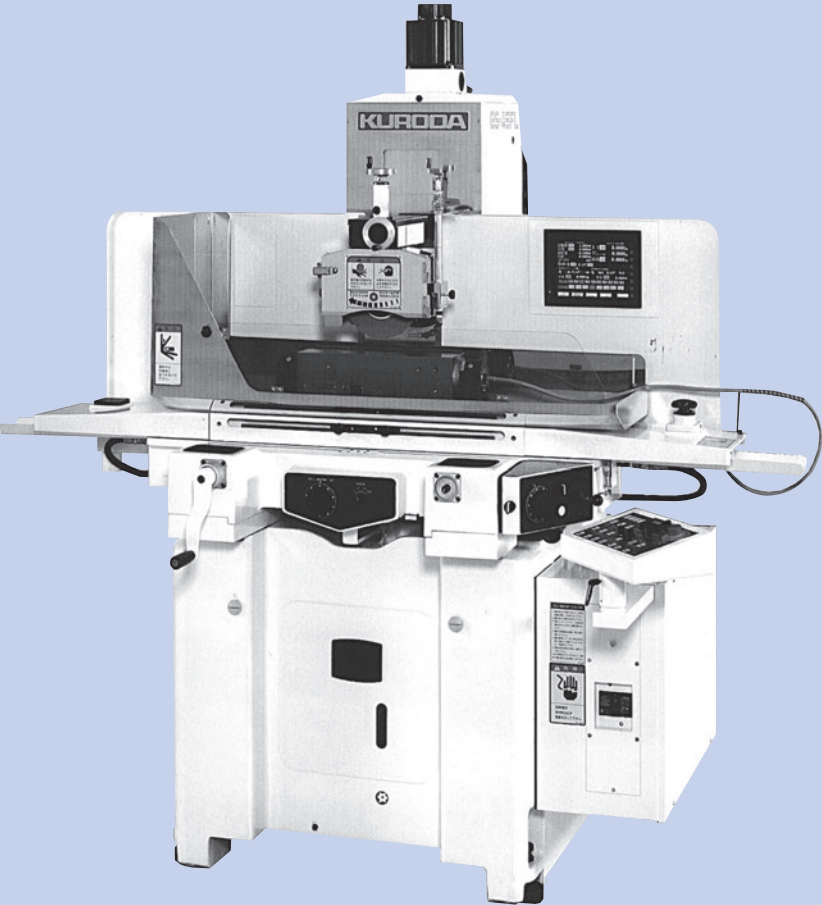
Surface grinding machine

LRX



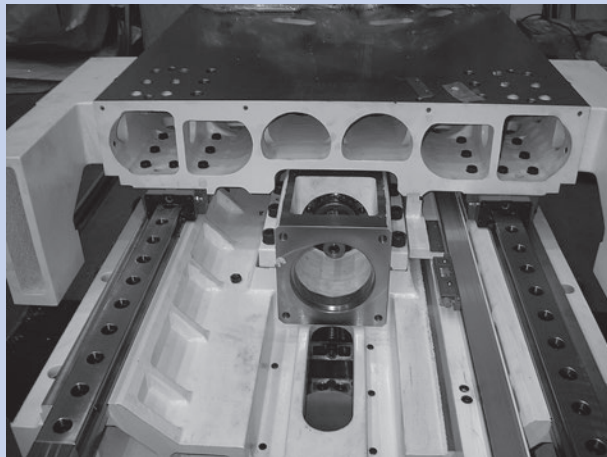
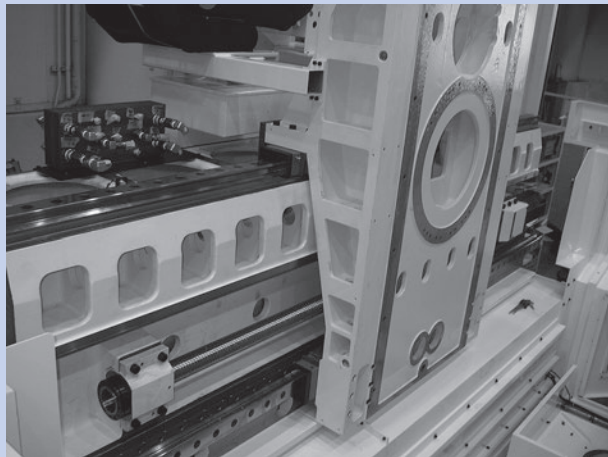
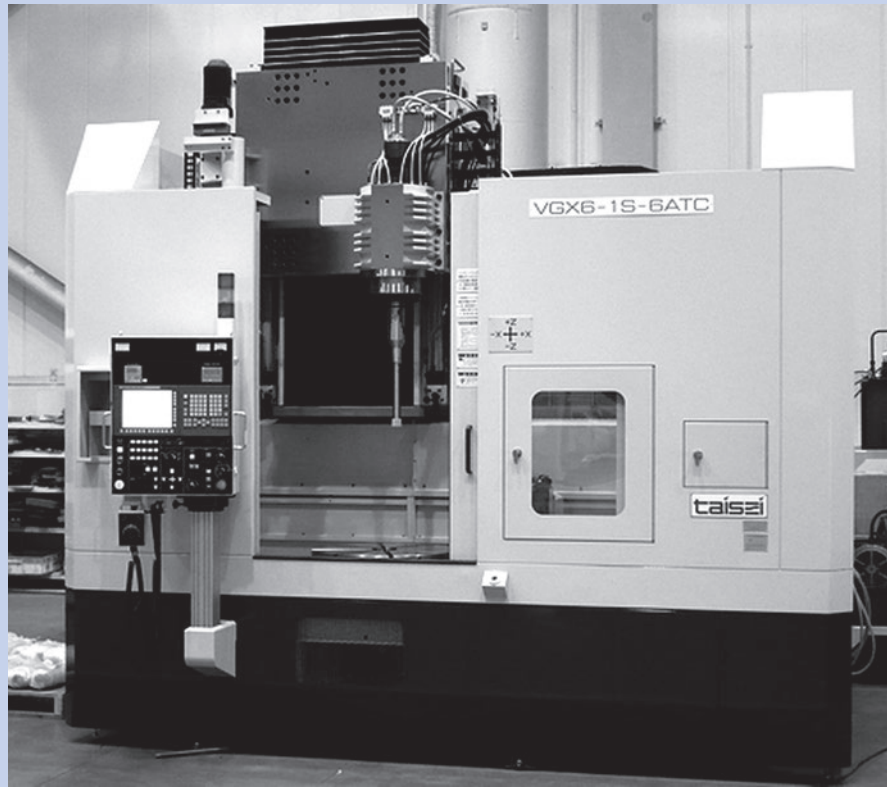
Precision forming surface grinding machine

MXD · LRXDG · MHD



Vertical grinding machine

MX • MXL



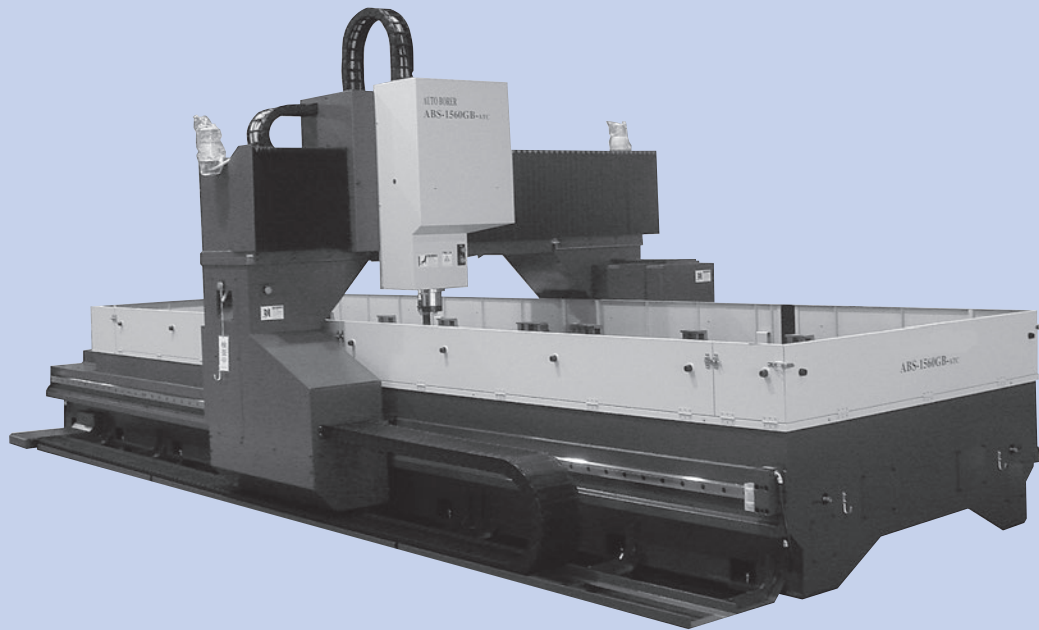
Tool grinding machine

LRXDG • LRXG



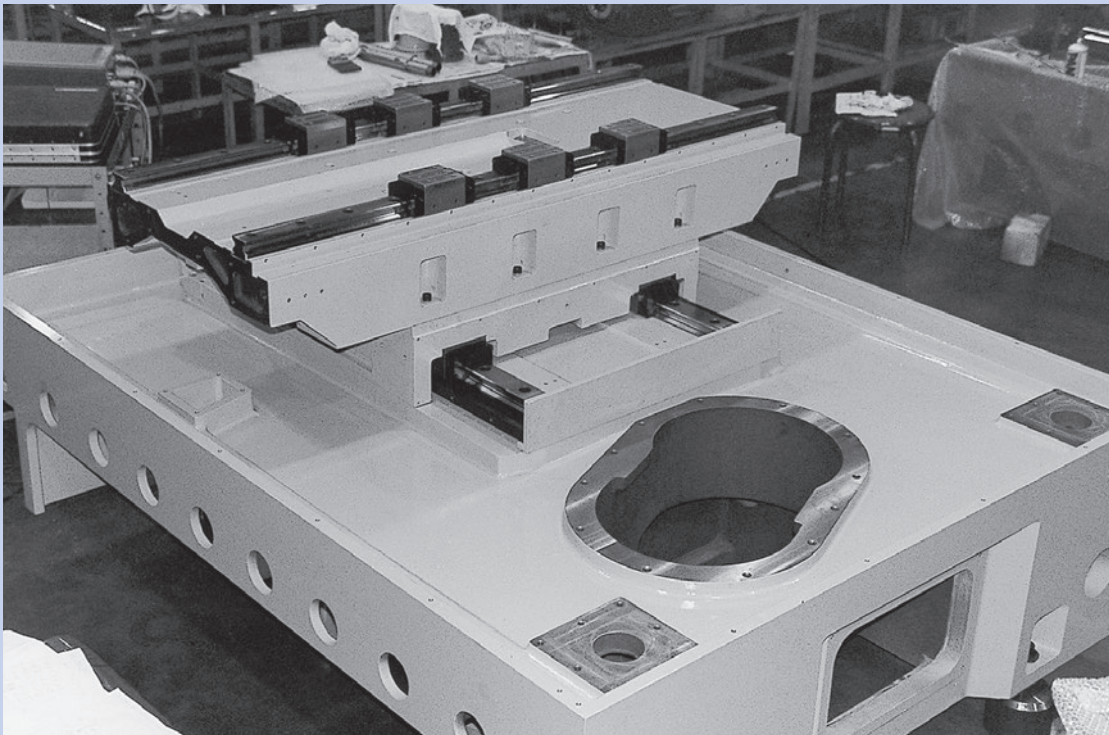
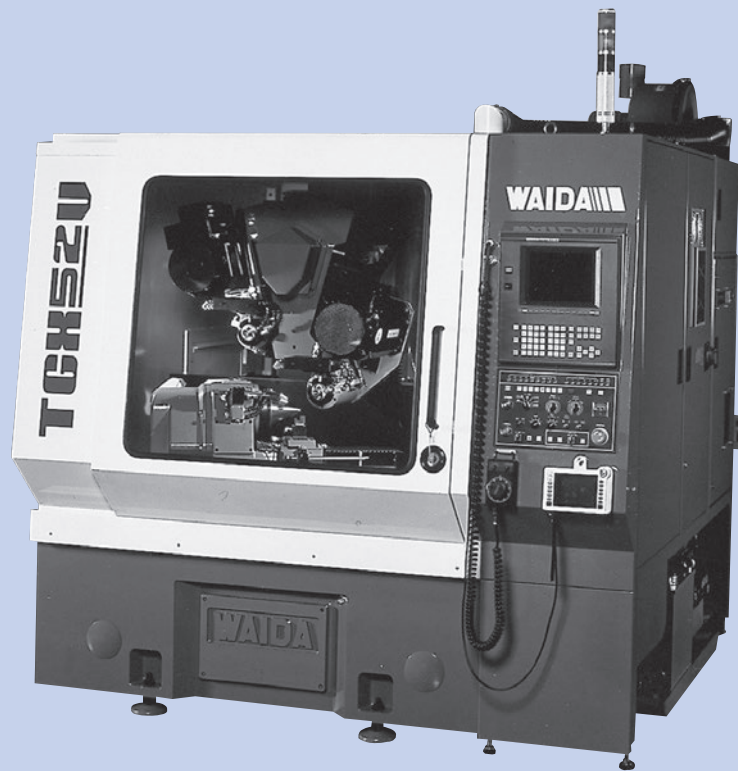
Multi-function drilling machine

MXG • MXNG • MXNSG



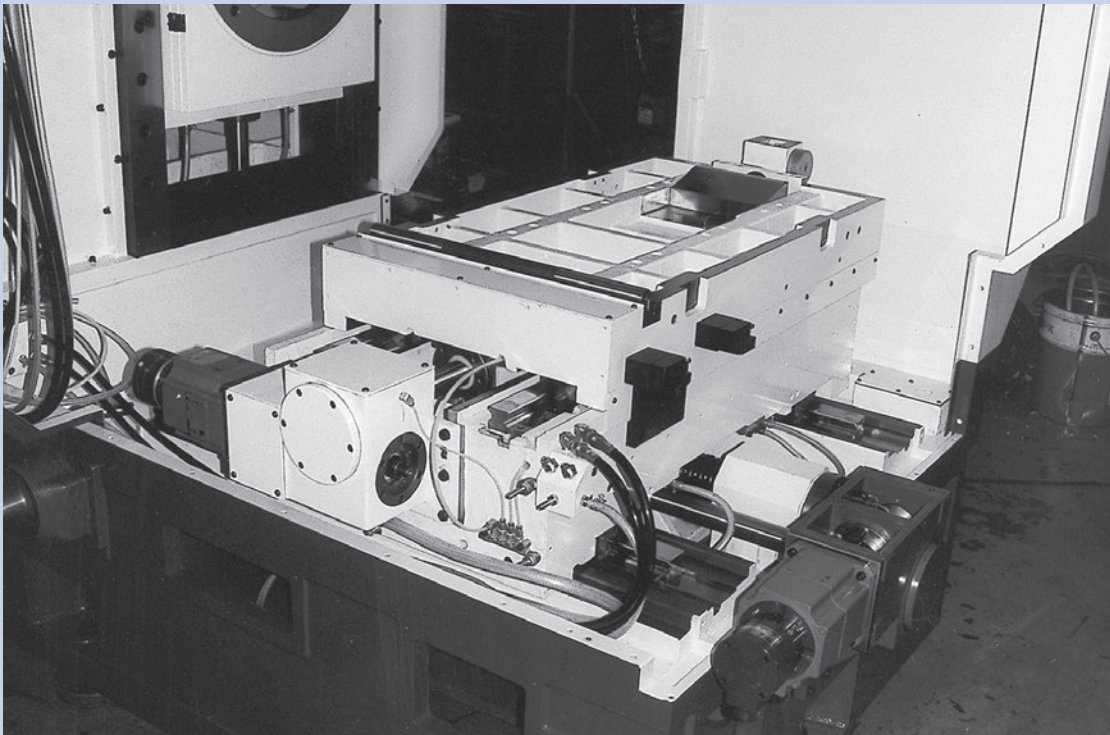
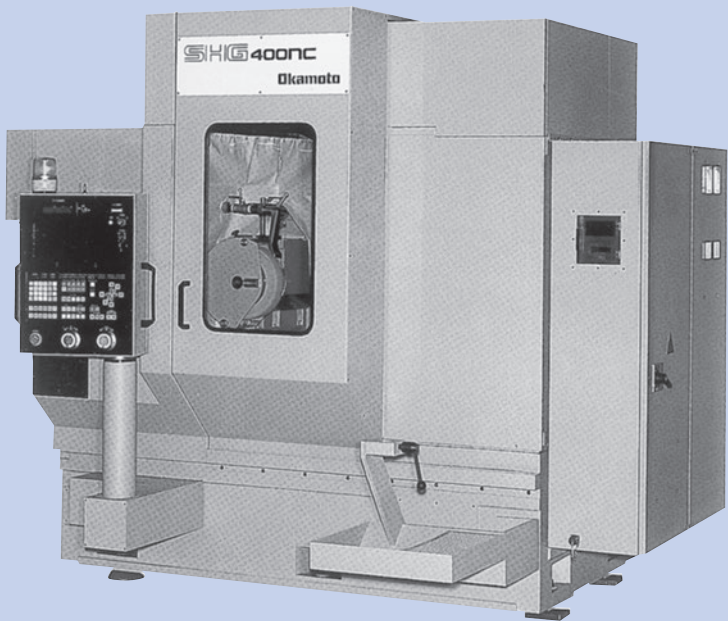
Tool grinding machine

LRXD · LRXDG



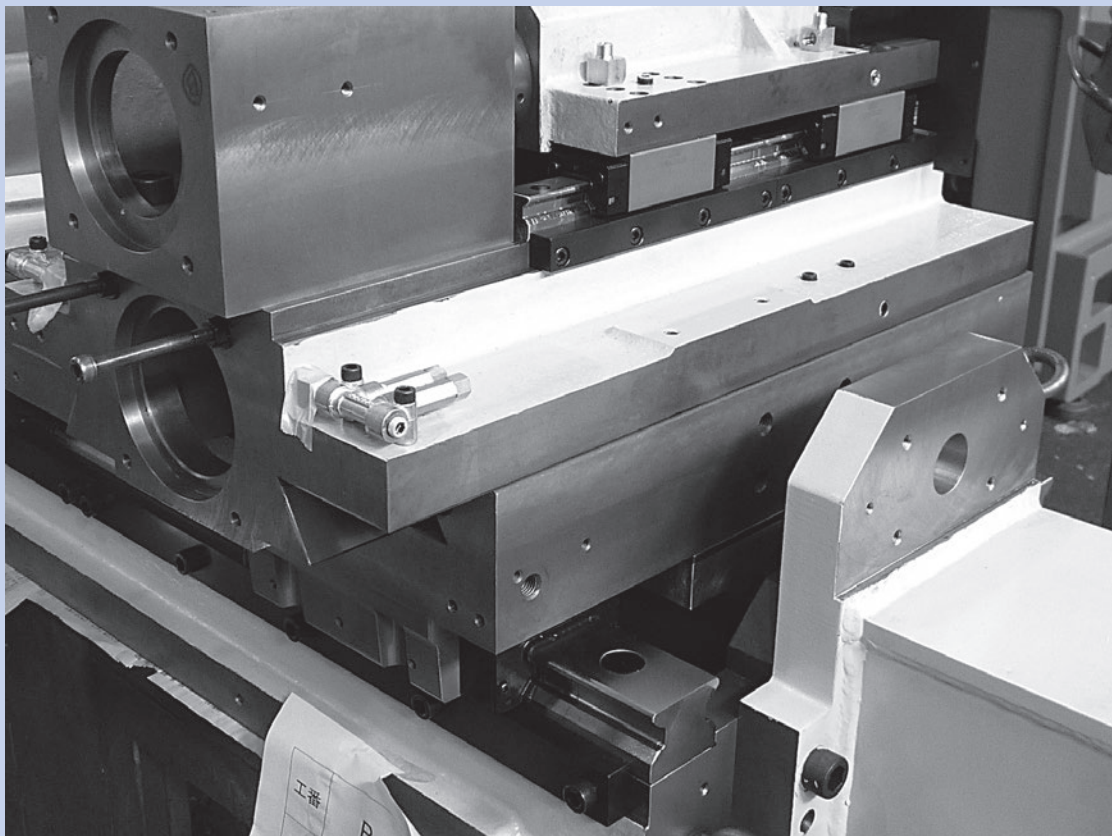
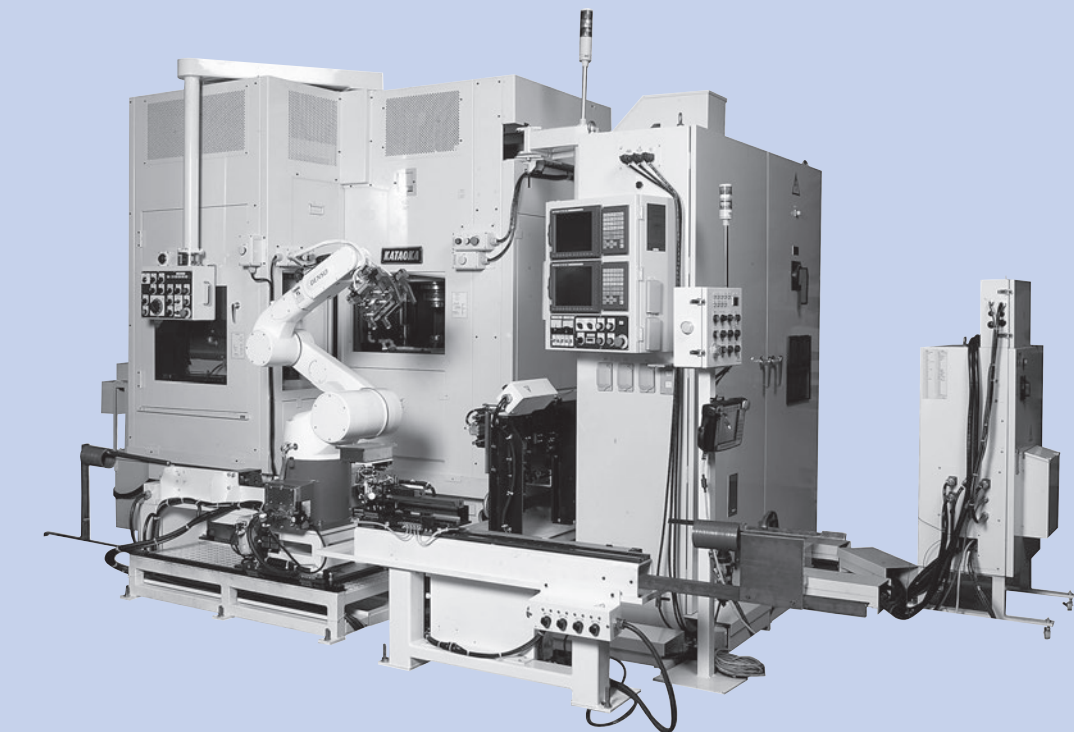
Synchronized control gear grinding machine

LRXG



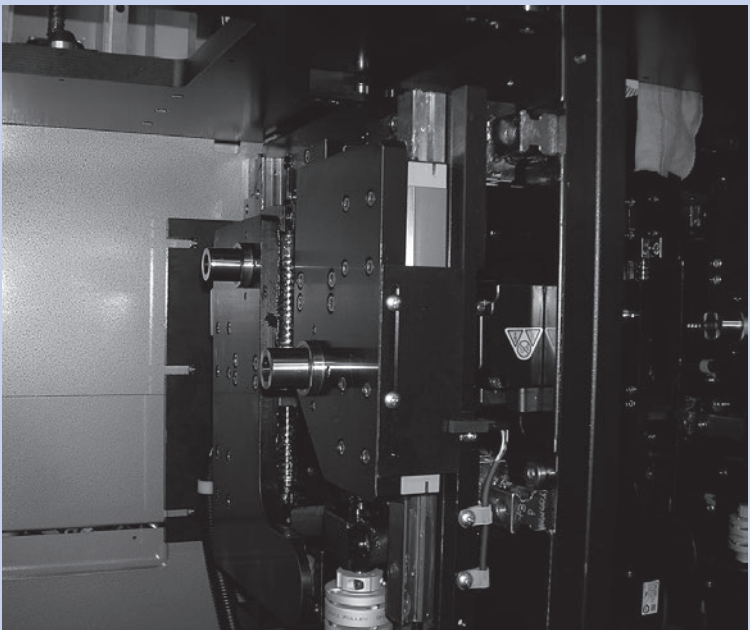
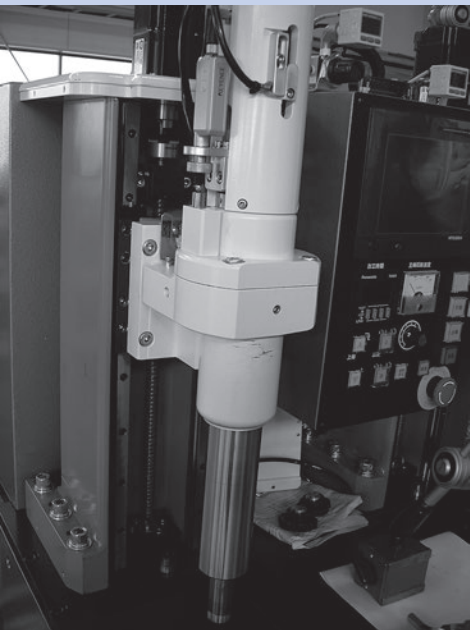
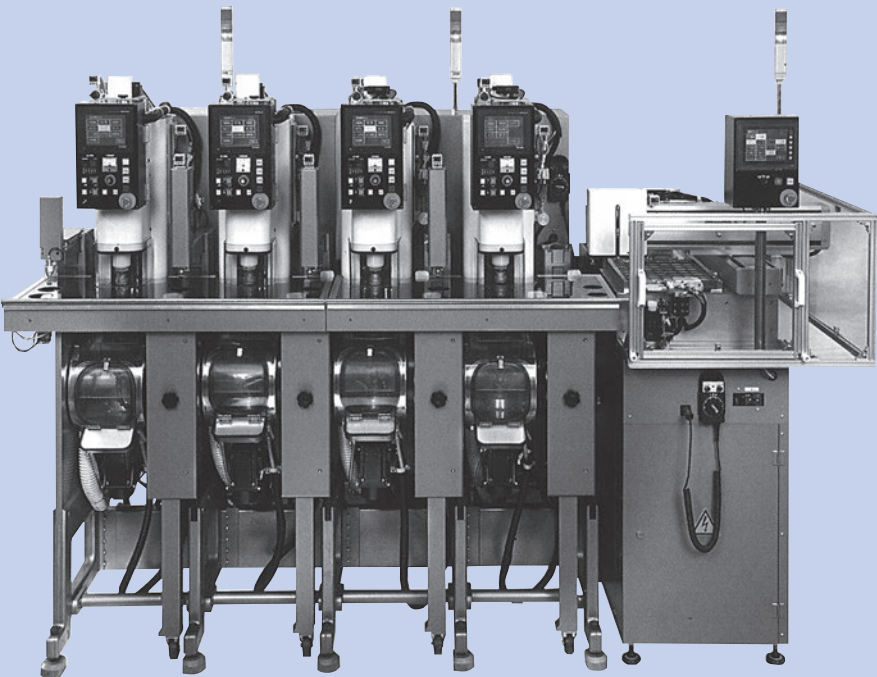
Piston ring grinding machine

LRXG · LRXD



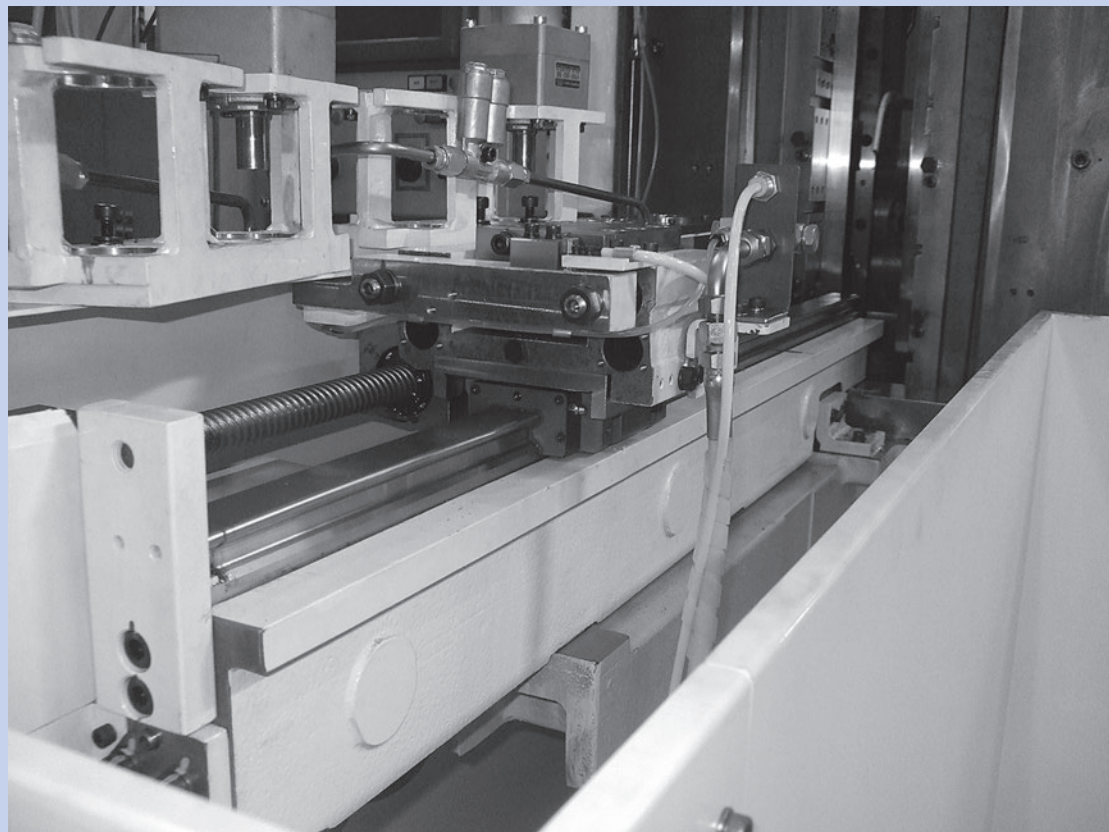
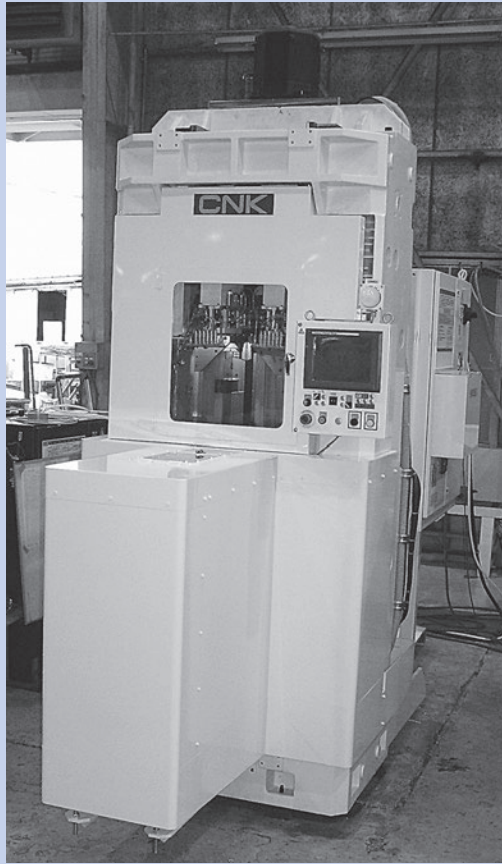
High precision NC lens polishing machine

MXD · LRXS



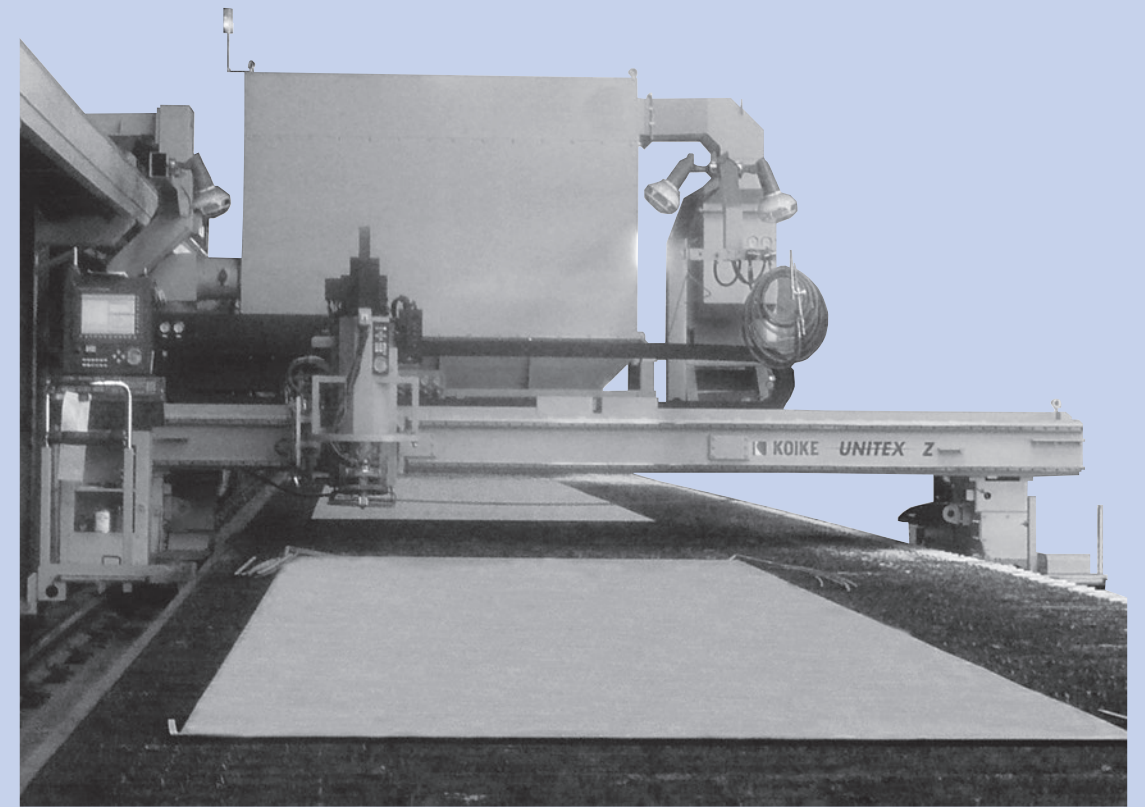
Roll forming machine

LRXG



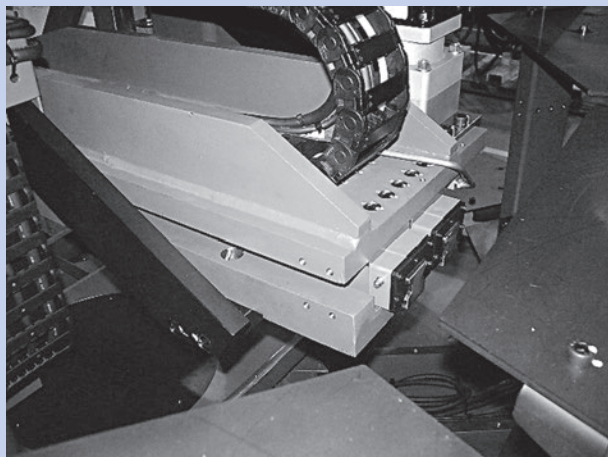
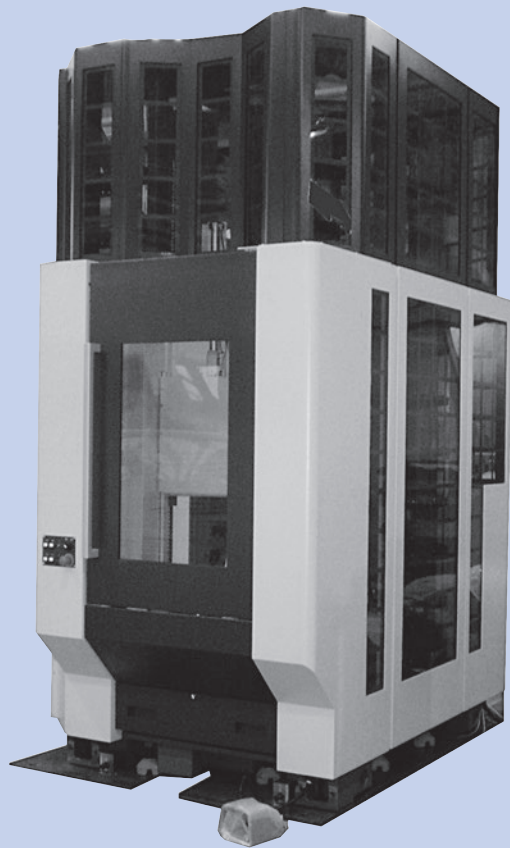
Plasma cutting machine

MXG



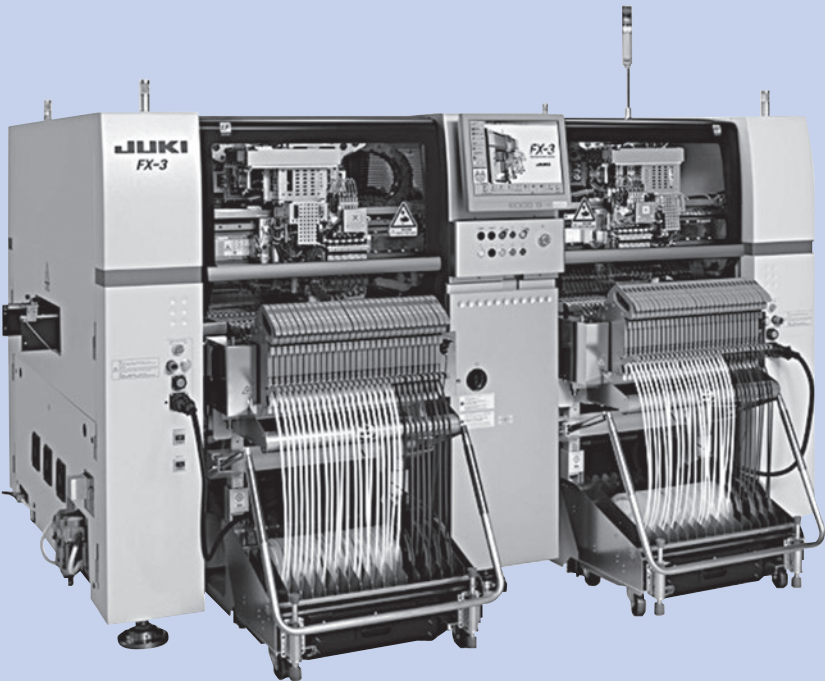
Automatic work changer for five-axis control vertical machining center

MXDG · MXDL



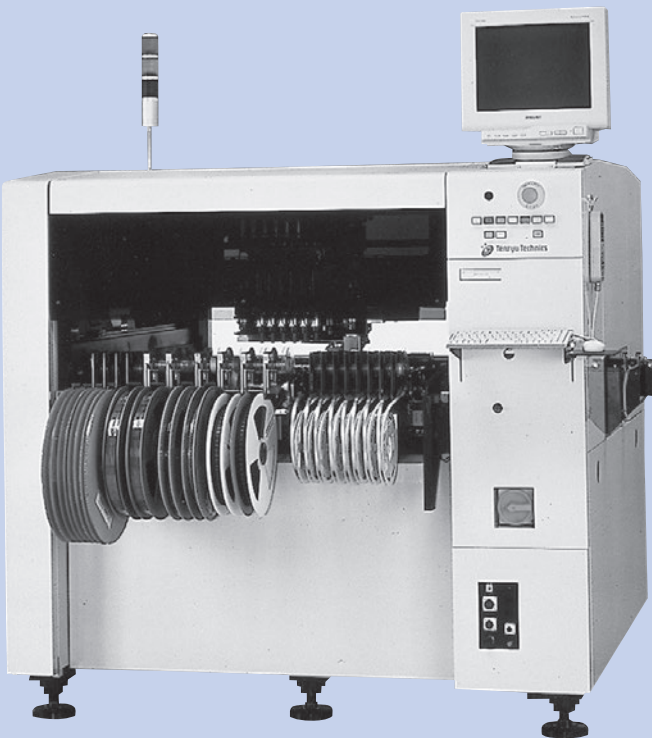
Chip mounter

MXSG · ML · MES · MHD



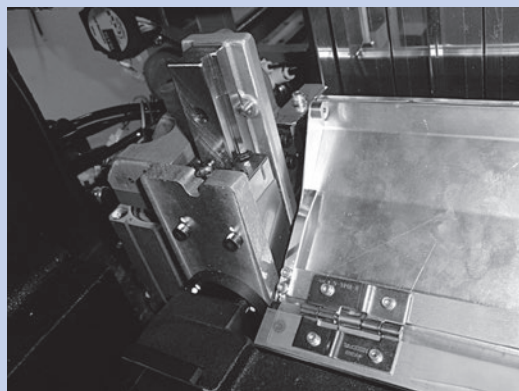
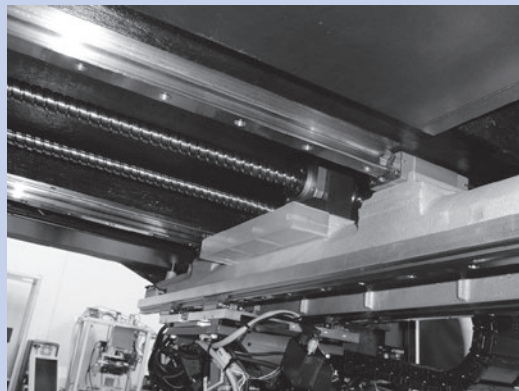
Chip mounter

LWLC



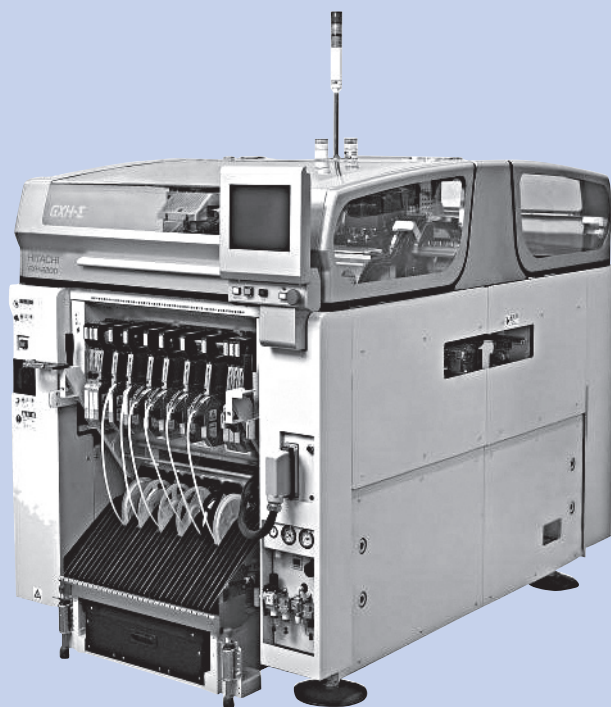
Twin head high-speed multi function mounter

MXS • MXSG • MLFG



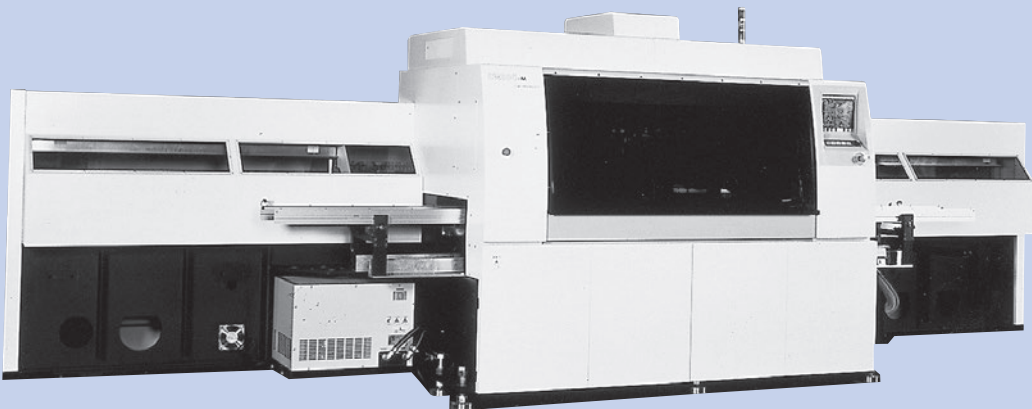
High-speed modular mounter

LRXD • MLG • MLF



High-speed chip mounter

LWLF • LWHS • LWHSG



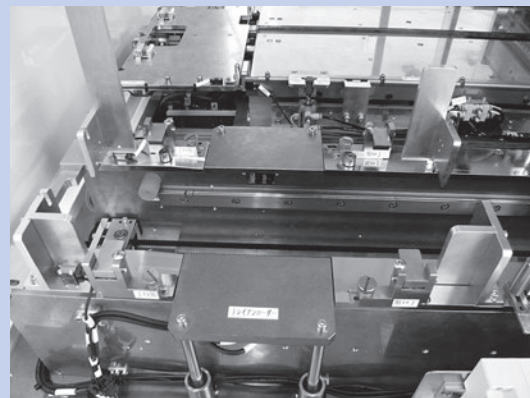
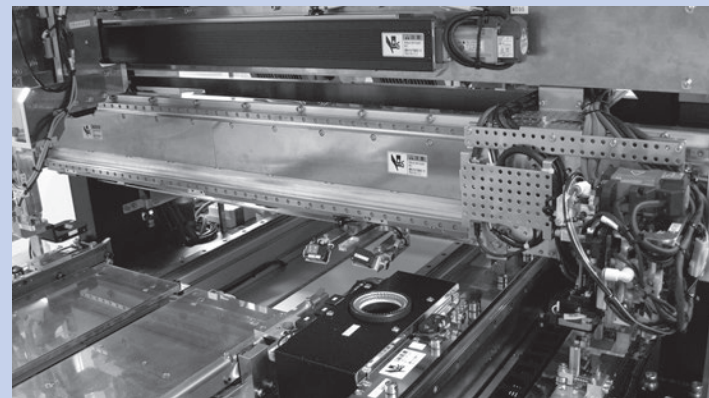
Stepper

LWL • LWLF • LWHS



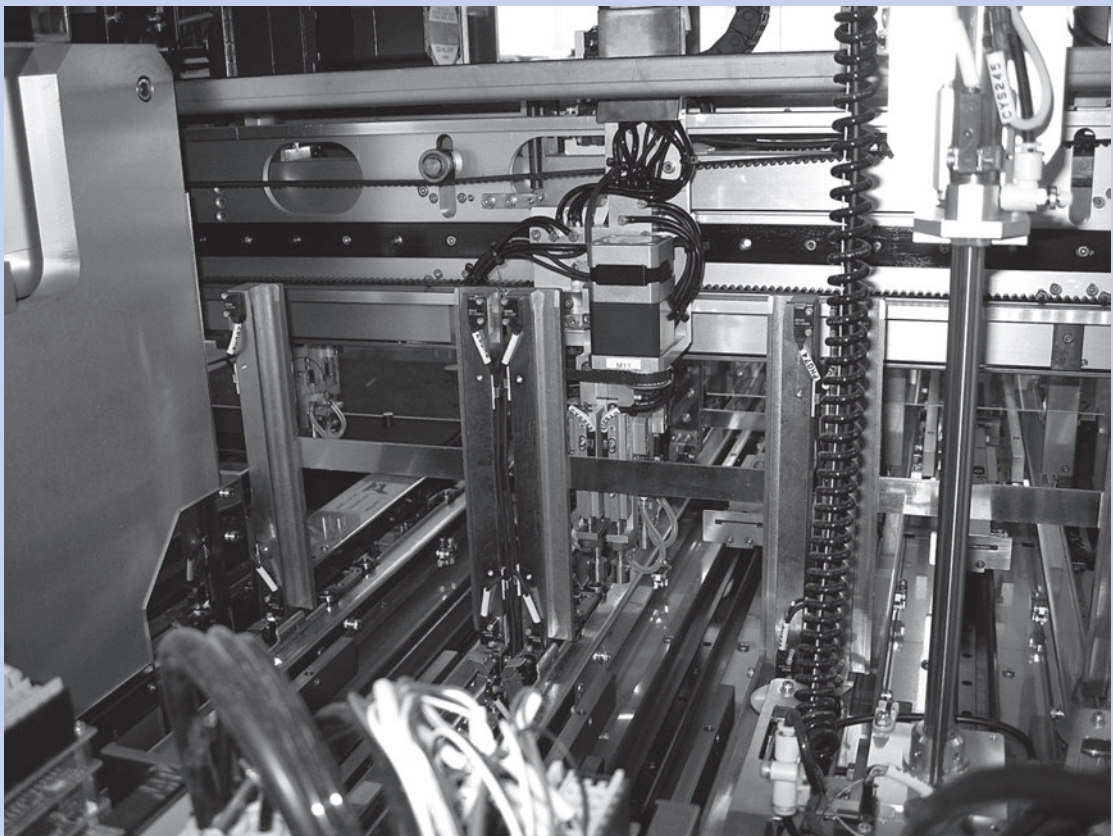
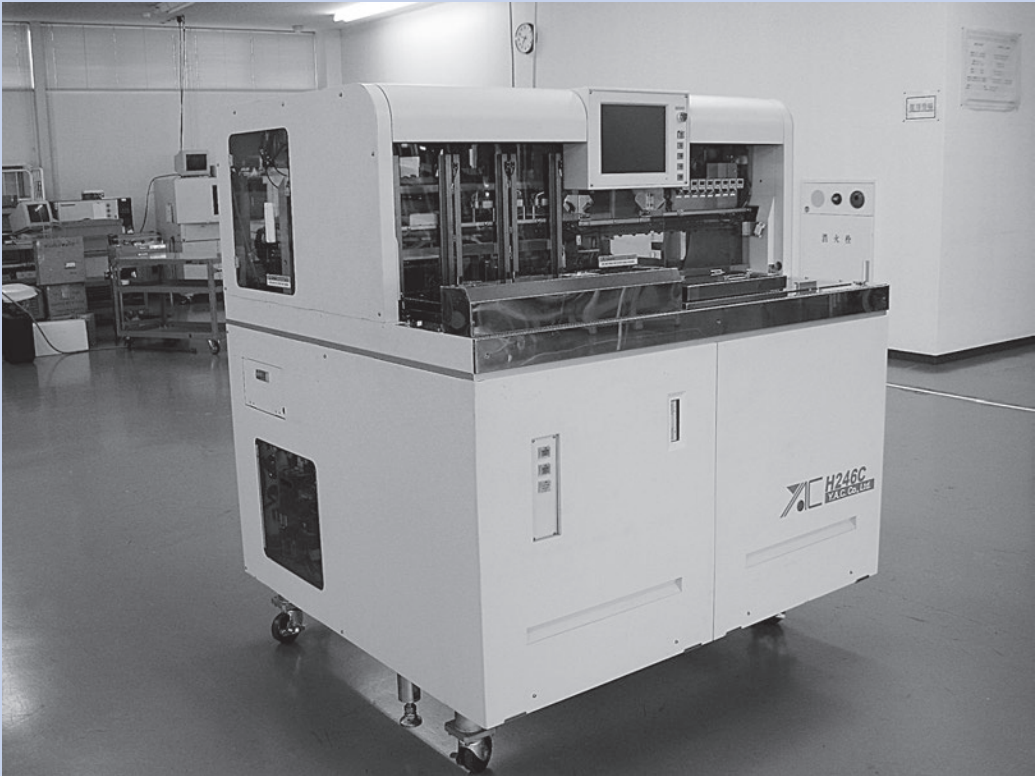
Burn-in handler

ML · LWHS



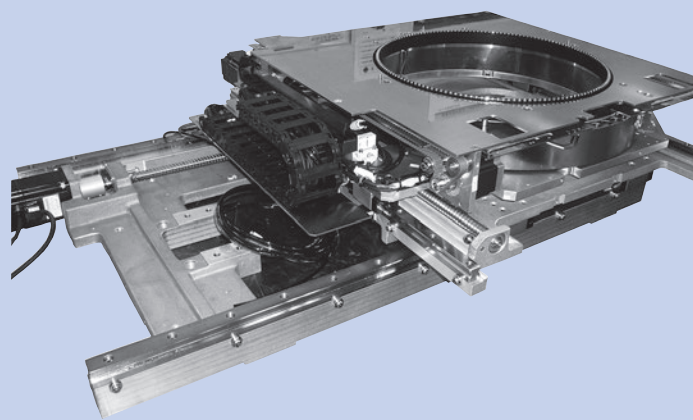
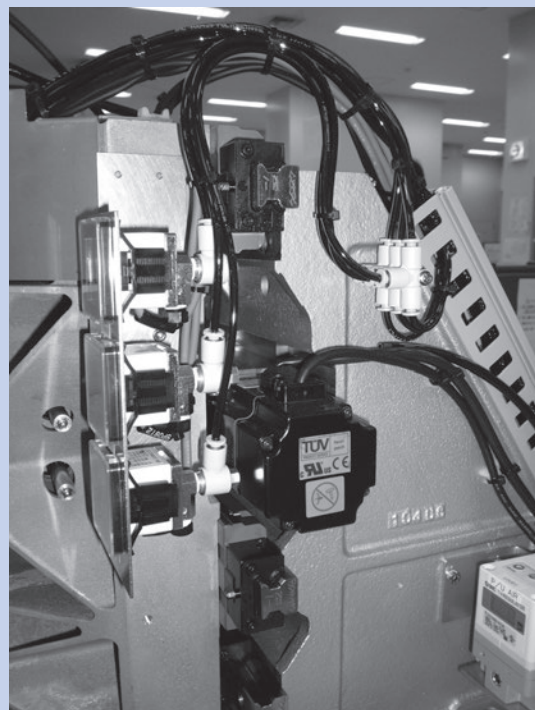
IC handler

LWHD



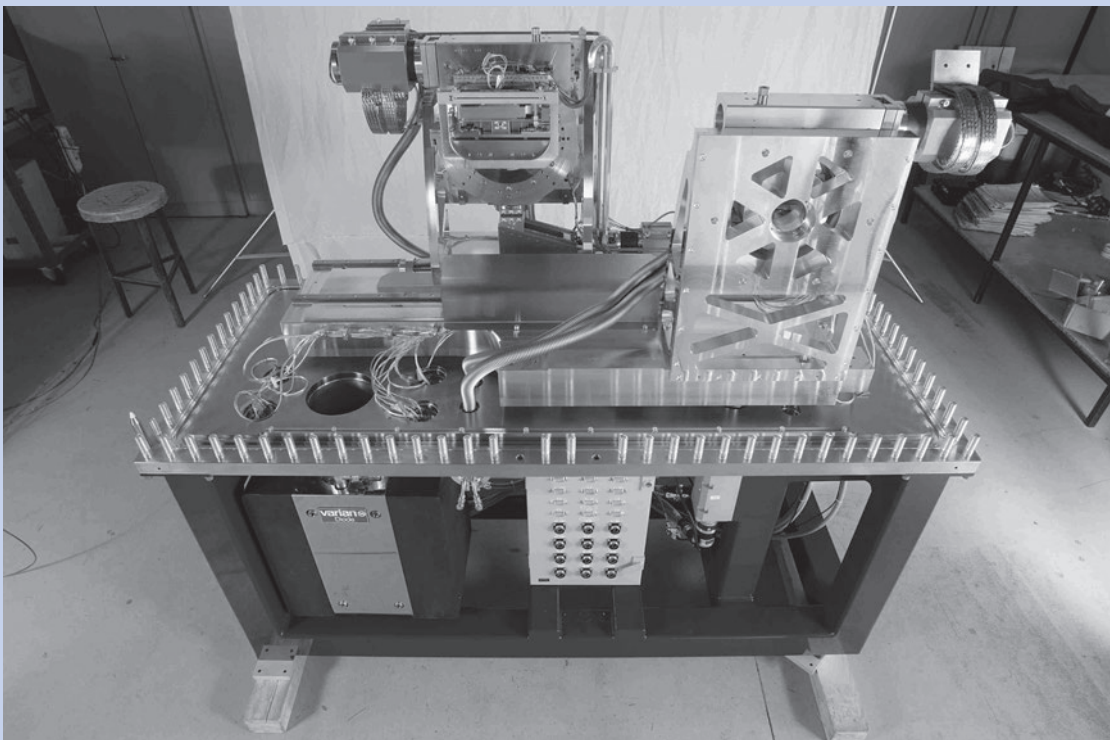
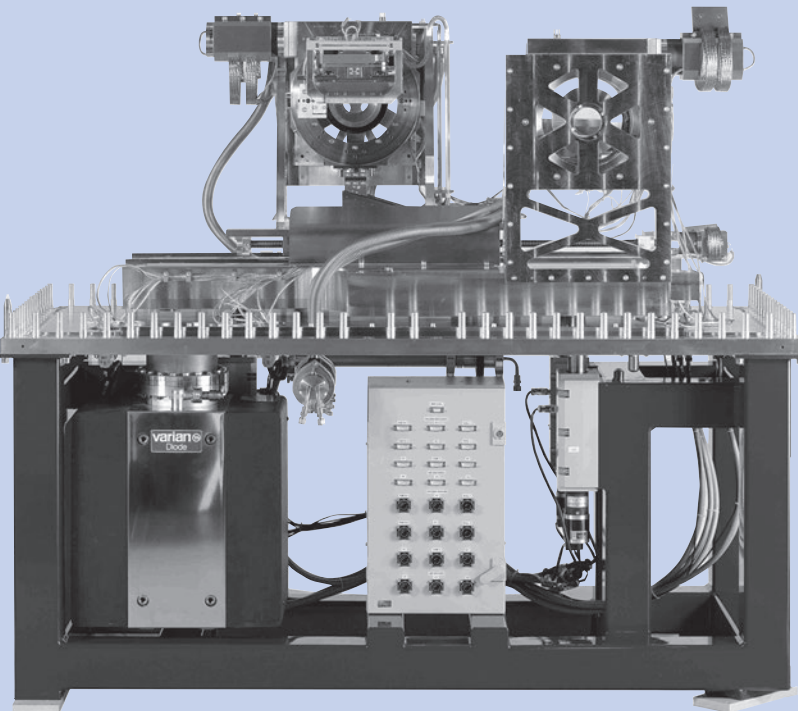
Die bonder

LRXD · LRXS



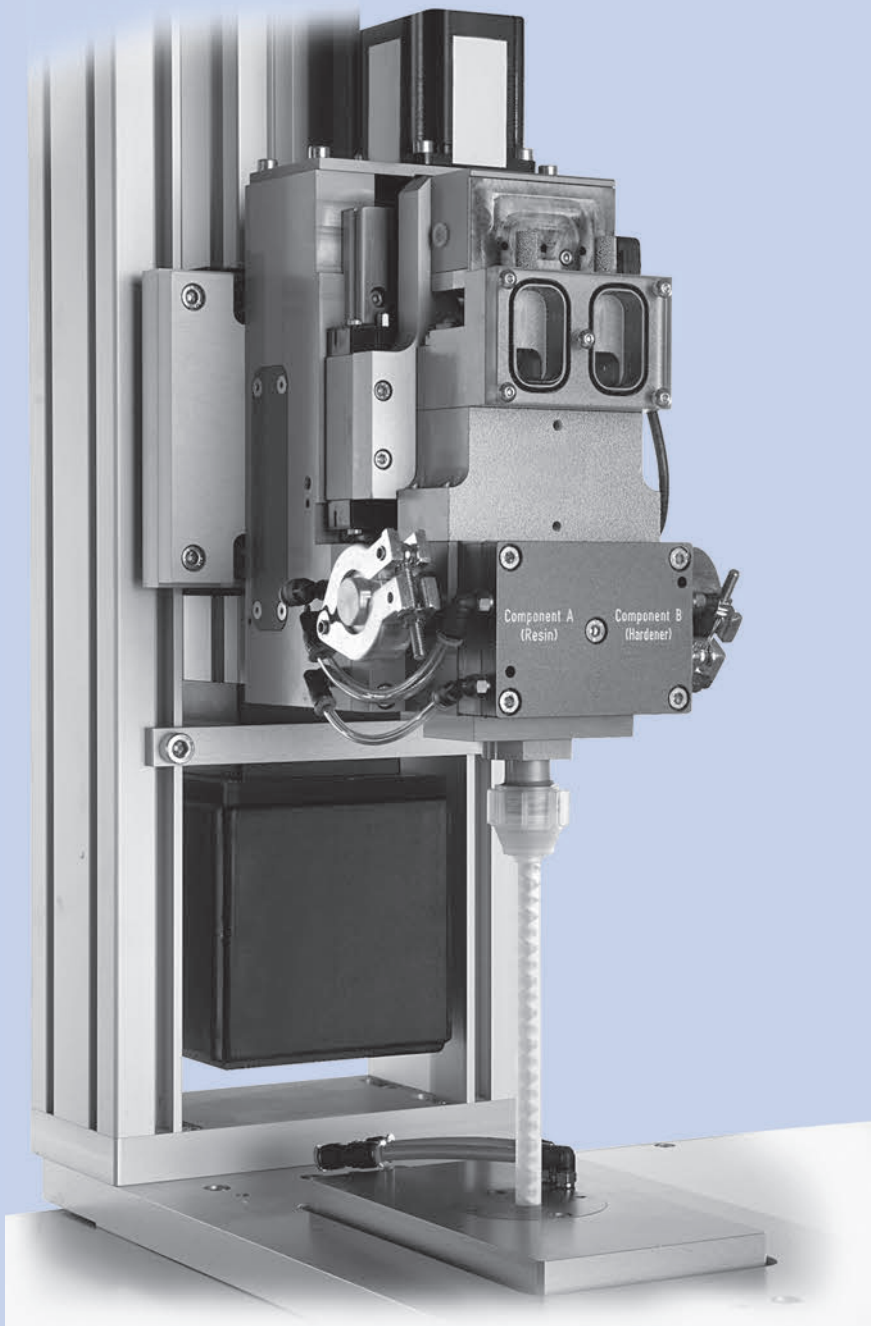
Spectroscope

LWL



Resin forming machine for electronics devises

LRXDG



Rotary offset printing machine

LWH · LWHDG



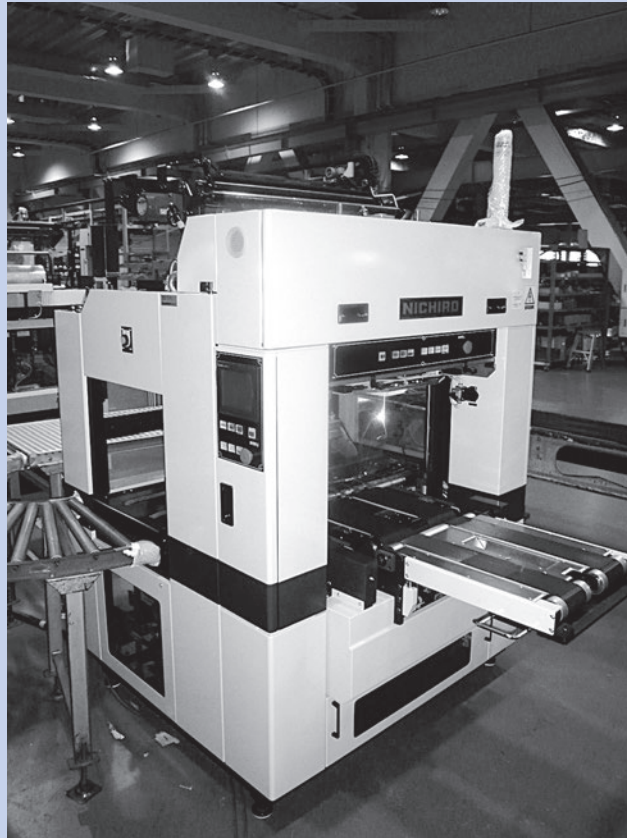
Multi-head type electronic embroidery machine

LWL



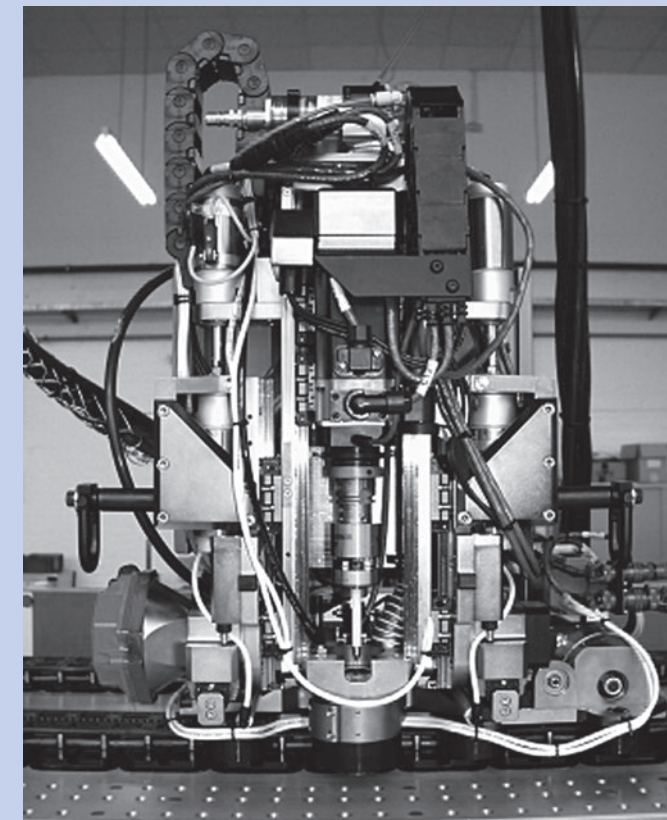
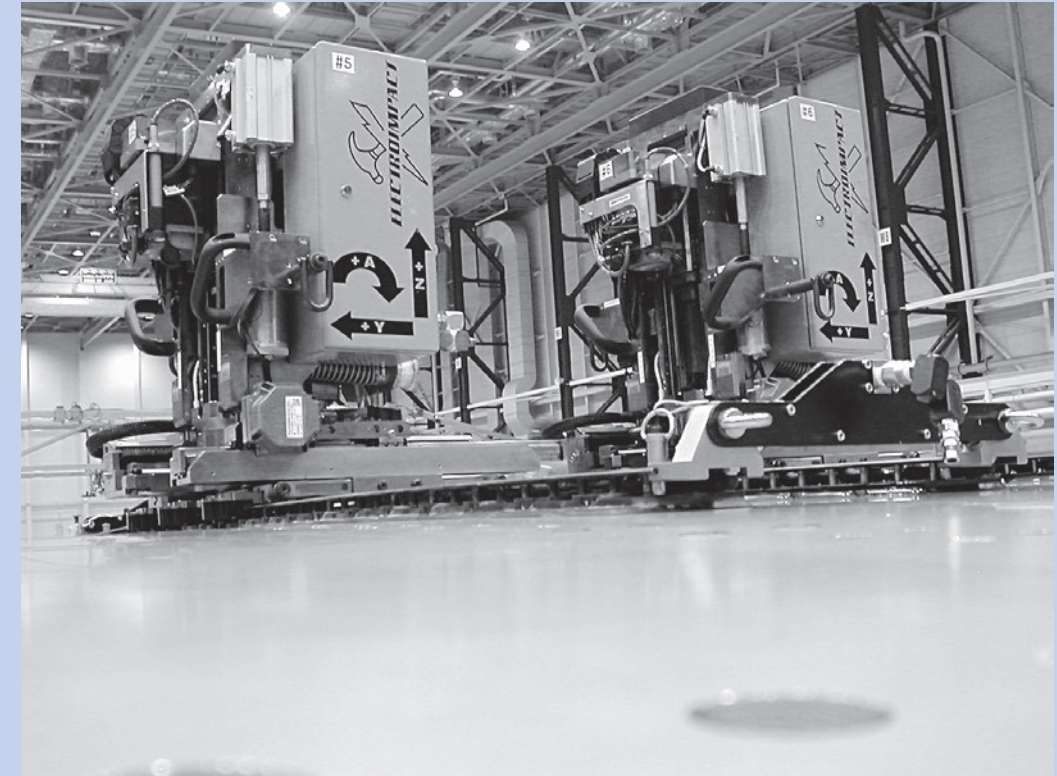
Newspaper packaging machine

LWHS



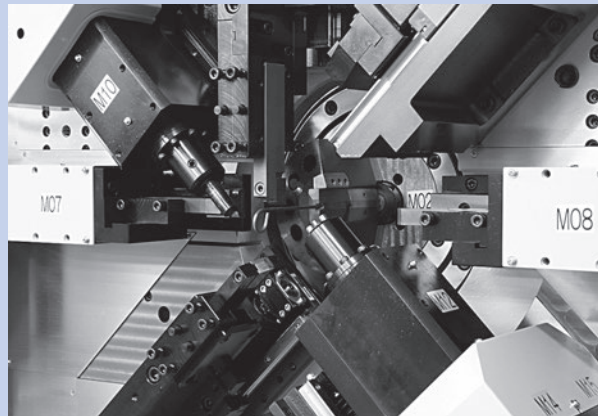
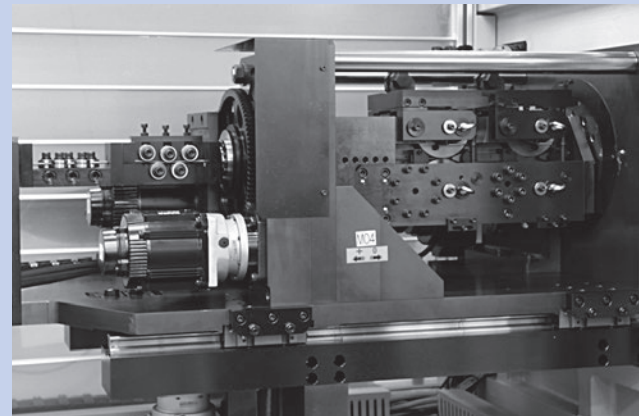
Welding machine for airplane body panels

LRXD • LWL



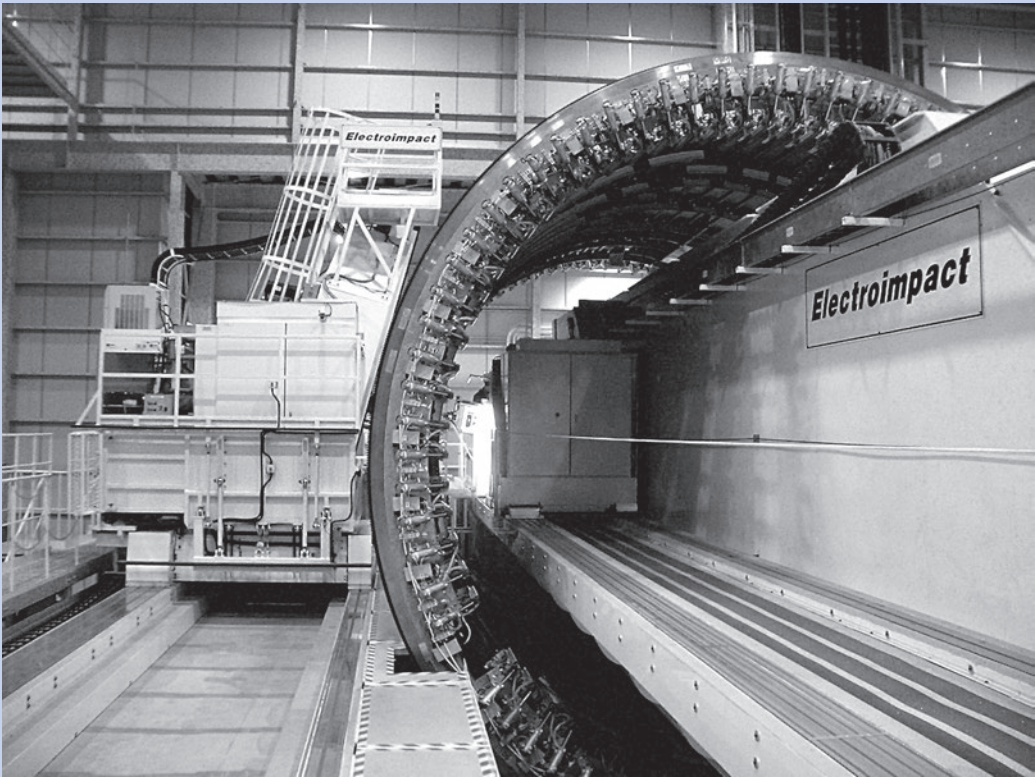
Spring forming machine

MXG • MXDG • MXSG • MXNSG



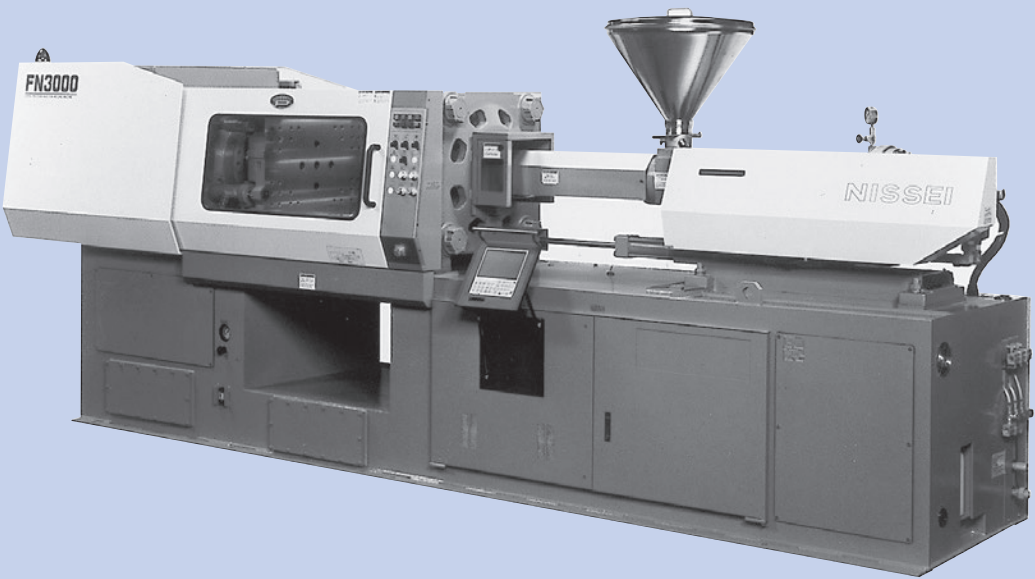
Locating machines for airplane body panels

LRX



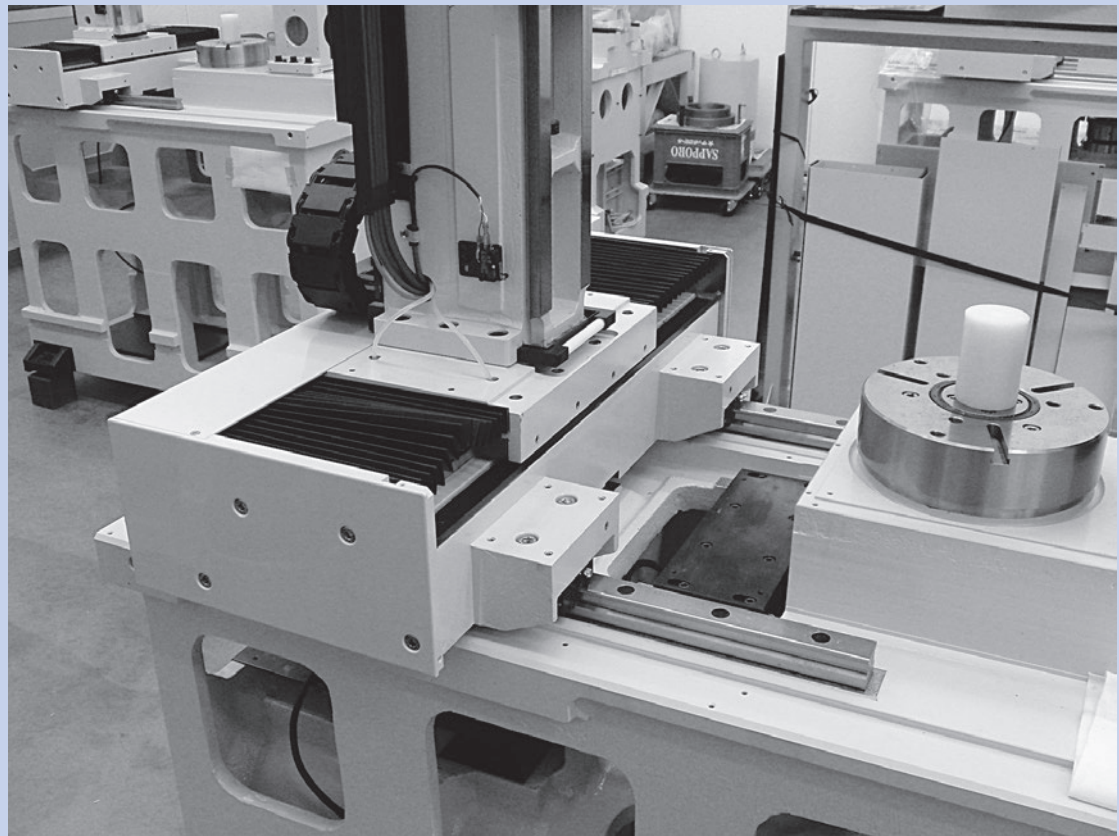
Injection molding machine

LWES



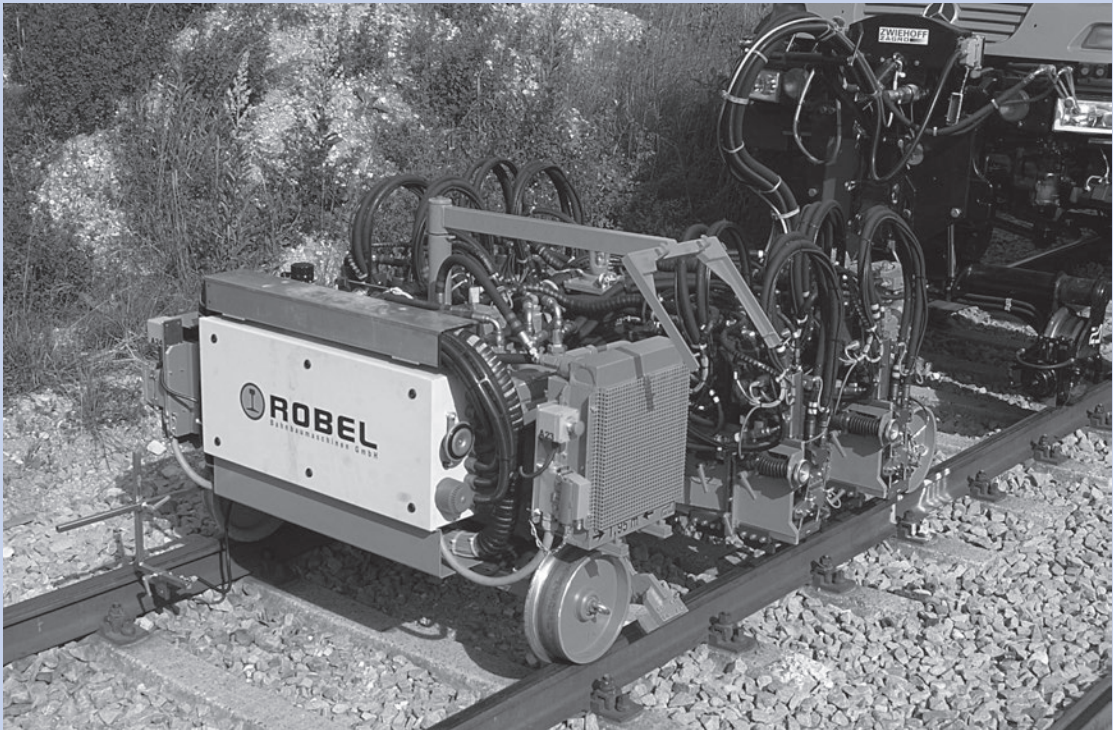
CNC gear profile inspection machine

LRX



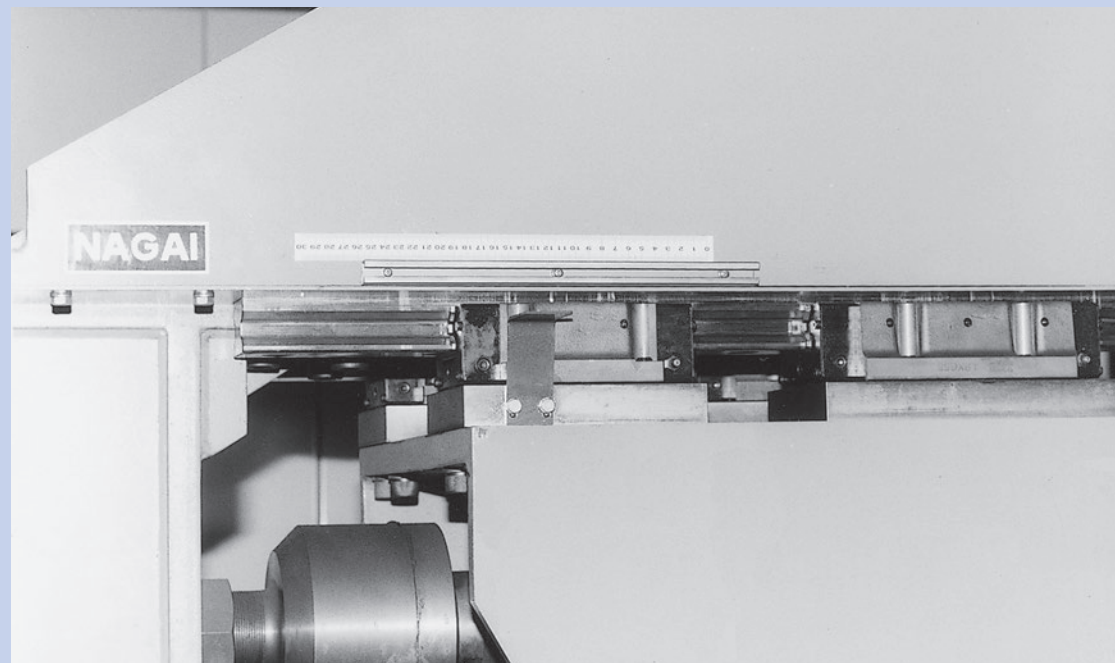
Maintenance machine for railroad application

LRXG



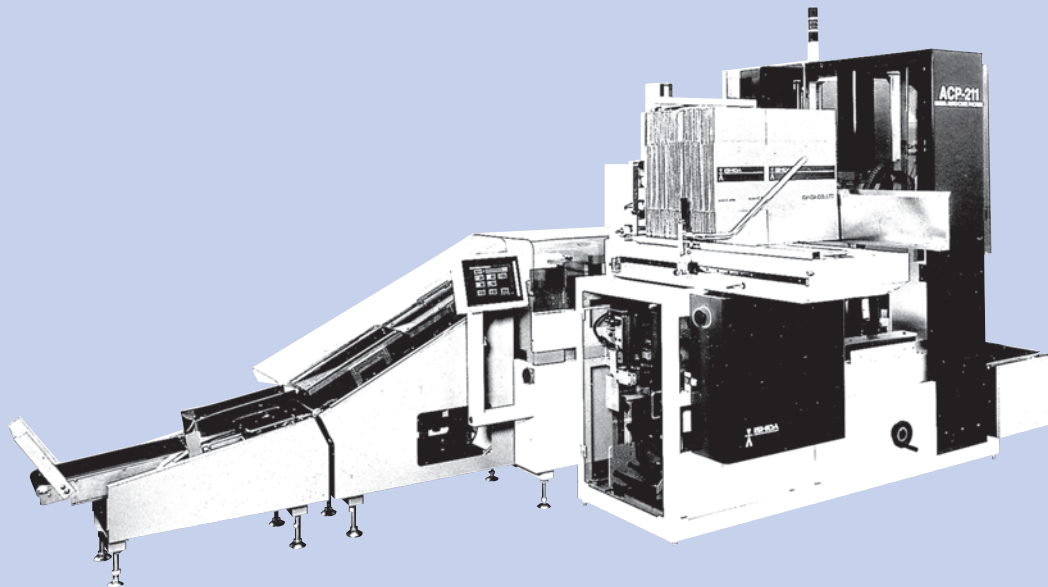
High pressure forming machine for wood materials

LRXG



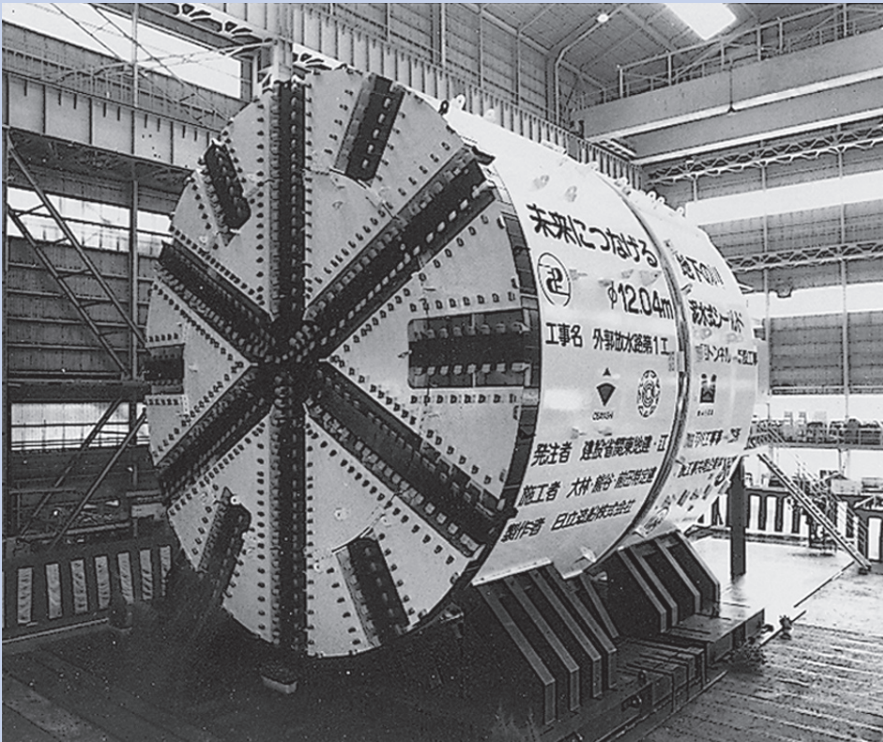
Automatic case packer

LWL • LWES • LWH • LWHS • LWHDG



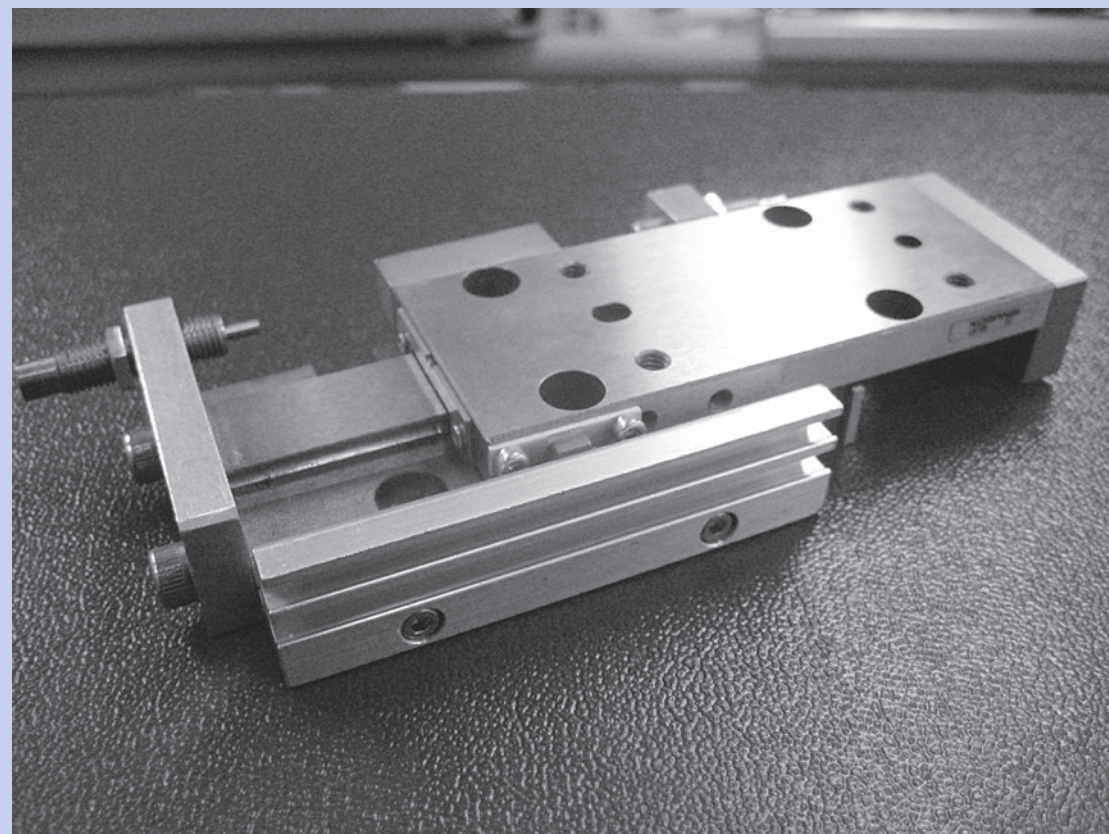
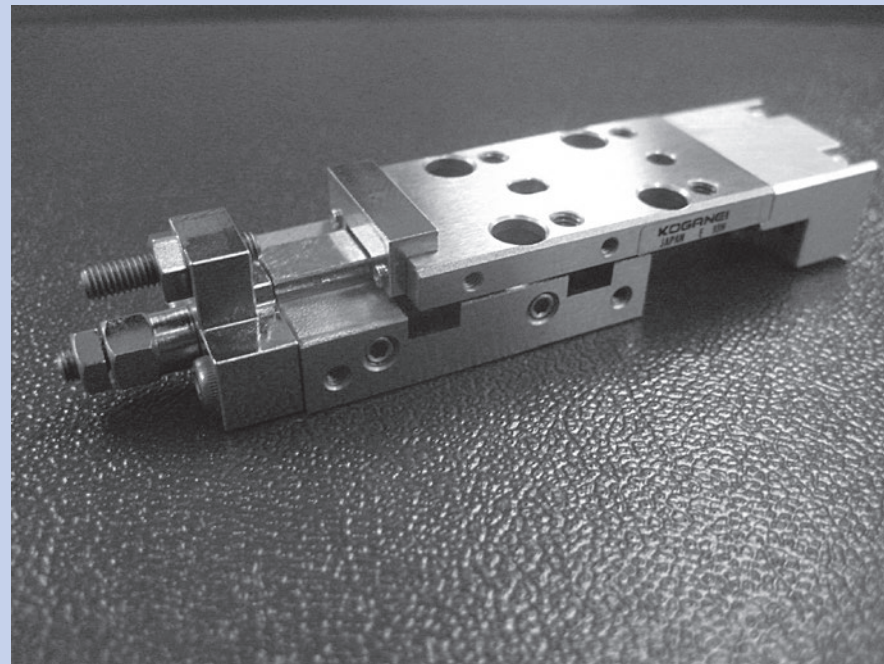
Shield type tunnel excavator

LRXDG • LWHS



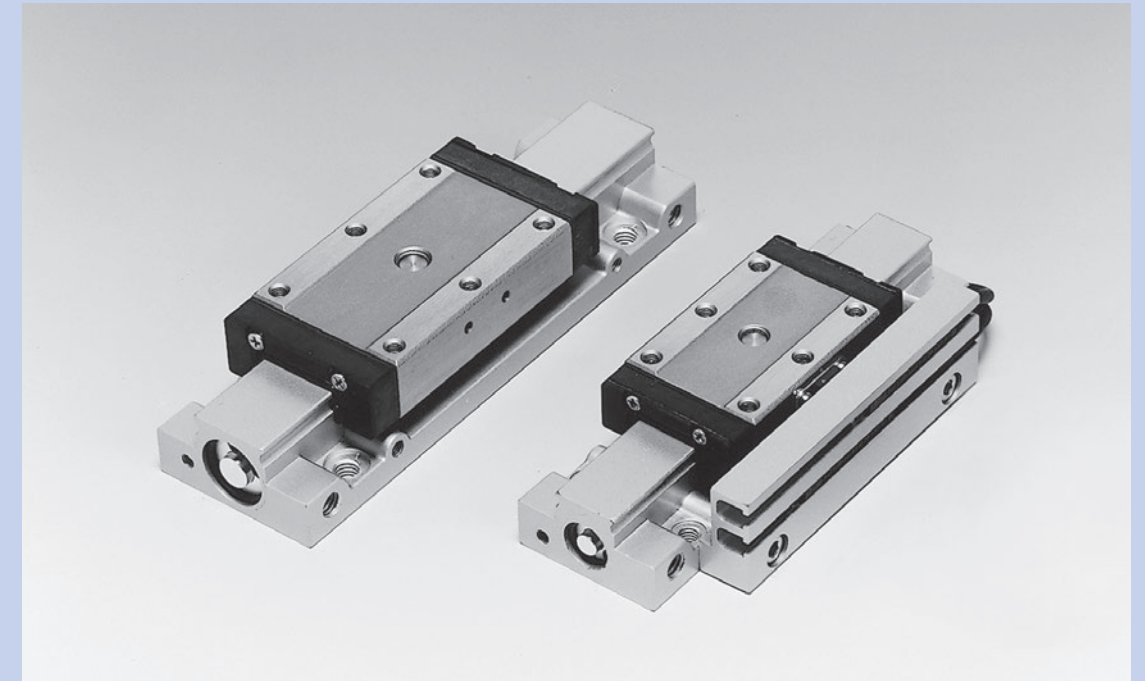
Pneumatic cylinder unit

LWL



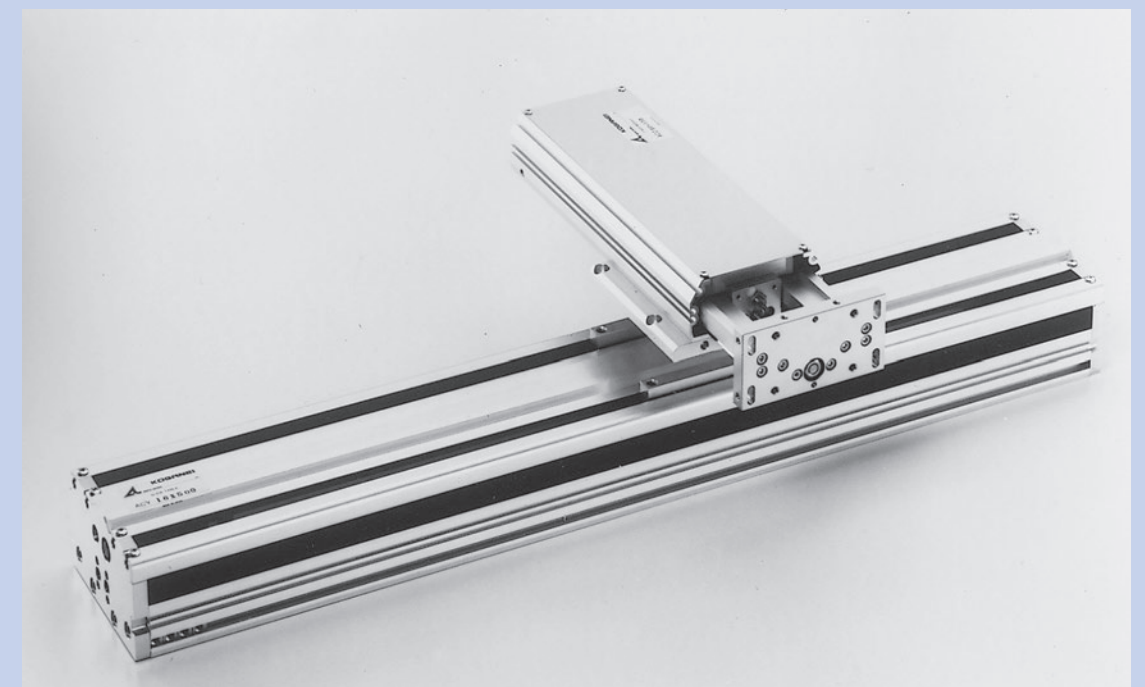
Pneumatic actuator

LWL



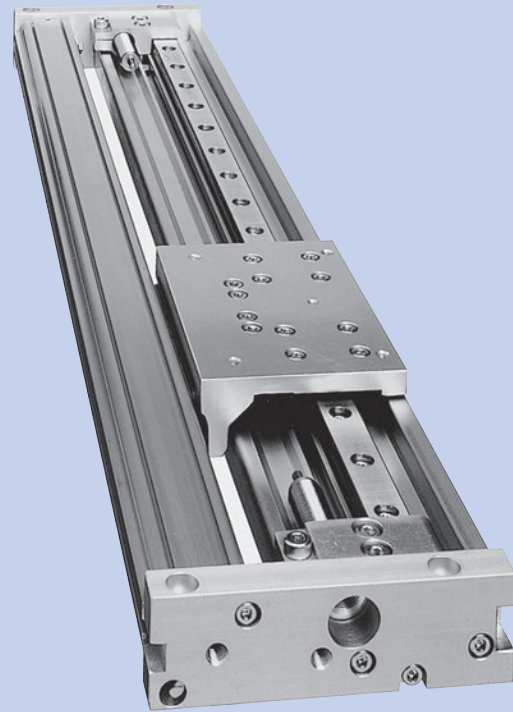
Pneumatic slide table

LWL



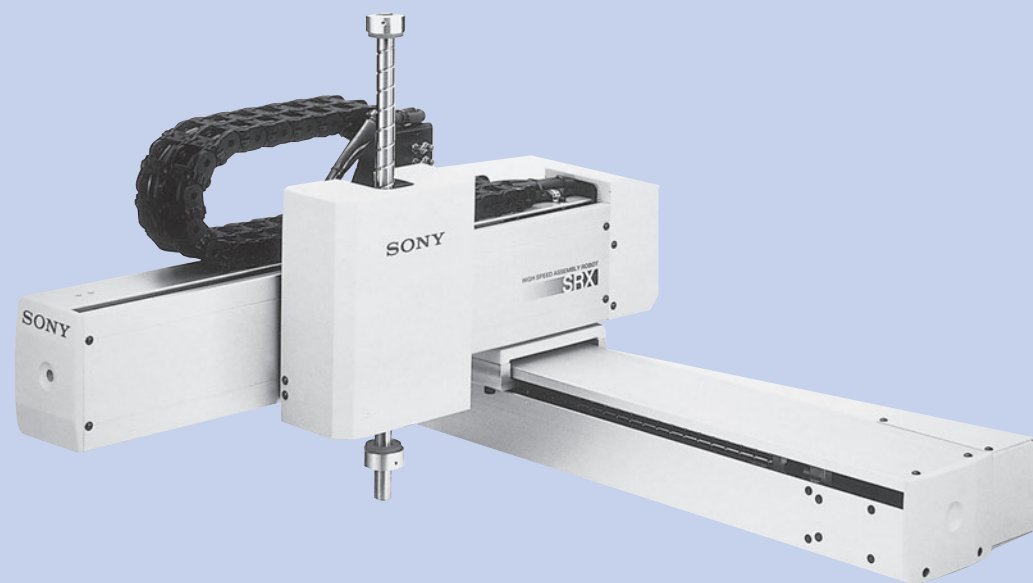
Rodless cylinder

LWL



XYZ-axis robot

LWHD



Reference tables

Statements

● Unit Conversion Rate Table

SI, CGS series and gravity system unit cross-reference table

Amount Unit system	Length	Mass	Time	Acceleration	Force	Stress and pressure
SI	m	kg	s	m/s ²	N	Pa
CGS series	cm	g	s	Gal	dyn	dyn/cm ²
Gravity system	m	kgf·s ² /m	s	m/s ²	kgf	kgf/m ²

SI unit conversion

Amount	Unit name	Code	SI conversion rate	SI unit name	Code
Angle	D	°	$\pi/180$	Radian	rad
	Min	'	$\pi/10\ 800$		
	Sec	″	$\pi/648\ 000$		
Length	Meter	m	1	Meter	m
	Micron	μ	10^{-6}		
	Angstrom	Å	10^{-10}		
	X ray unit		$\approx 1.002\ 08\times 10^{-13}$		
	Nautical mile	n mile	1852		
Area	Square meter	m ²	1	Square meter	m ²
	Are	a	10^2		
	Hectare	ha	10^4		
Volume	Cubic meter	m ³	1	Cubic meter	m ³
	Liter	l, L	10^{-3}		
Mass	Kilogram	kg	1	Kilogram	kg
	Ton	t	10^3		
	Atomic mass unit	u	$\approx 1.660\ 57\times 10^{-27}$		
Time	Sec	s	1	Sec	s
	Min	min	60		
	Hr	h	3 600		
	Day	d	86 400		
Velocity	Meter per second	m/s	1	Meter per second	m/s
	Knot	kn	$1\ 852/3\ 600$		
Frequency and vibration	Number of cycle	s ⁻¹	1	Hertz	Hz
Number of rotations	Rotation per minute	min ⁻¹	1/60	Per second	s ⁻¹
Angular velocity	Radian per second	rad/s	1	Radian per second	rad/s
Acceleration	Meter per second	m/s ²	1	Meter per second	m/s ²
	G	G	9.806 65		
Force	Weight in kg	kgf	9.806 65	Newton	N
	Weight in ton	tf	9 806.65		
	Dyne	dyn	10^{-5}		
Force moment load	Weight in kg meter	kgf·m	9.806 65	Newton meter	N·m
Stress and pressure	Weight in kg per square meter	kgf/m ²	9.806 65	Pascal	Pa
	Weight in kg per square cm	kgf/cm ²	$9.806\ 65\times 10^4$		
	Weight in kg per square mm	kgf/mm ²	$9.806\ 65\times 10^6$		

Energy	Power	Temperature	Viscosity	Kinetic viscosity	Flux	Flux density	Magnetic field intensity
J	W	K	Pa·s	m ² /s	Wb	T	A/m
erg	erg/s	℃	P	St	Mx	Gs	Oe
kgf·m	kgf·m/s	℃	kgf·s/m ²	m ² /s	—	—	—

Amount	Unit name	Code	SI conversion rate	SI unit name	Code
Pressure	Meter water column	mH ₂ O	9 806.65	Pascal	Pa
	millimeter of mercury column	mmHg	$101\ 325/760$		
	Torr	Torr	$101\ 325/760$		
	Air pressure	atm	101 325		
	Bar	bar	10^5		
Energy	Erg	erg	10^{-7}	Joule	J
	IT calorie	cal _{IT}	4.186 8		
	Weight in kg meter	kgf·m	9.806 65		
	Kilowatt per hour	kW·h	3.600×10^6		
	French horse-power per hour	PS·h	$\approx 2.647\ 79\times 10^6$		
Power and motivity	Electron volt	eV	$\approx 1.602\ 19\times 10^{-19}$	Watt	W
	Watt	W	1		
	French horse-power	PS	≈ 735.5		
	Weight in kg meter per second	kgf·m/s	9.806 65		
Viscosity	Poise	P	10^{-1}	Pascal second	Pa·s
	Centipoise	cP	10^{-3}		
	Weight in kg second per square meter	kgf·s/m ²	9.806 65		
Kinetic viscosity	Stokes	St	10^{-4}	Square meter per second	m ² /s
	Centistokes	cSt	10^{-6}		
Temperature	D	℃	+273.15	Kelvin	K
Radioactivity	Curie	Ci	3.7×10^{10}	Becquerel	Bq
	Exposure radiation dose	R	2.58×10^{-4}		
	Absorbed dose	rad	10^{-2}		
	Dose equivalent	rem	10^{-2}		
Flux	Maxwell	Mx	10^{-8}	Weber	Wb
Flux density	Gamma	γ	10^{-9}	Tesla	T
	Gauss	Gs	10^{-4}		
Magnetic field intensity	Oersted	Oe	$10^3/4\pi$	Ampere per meter	A/m
Electric charge	Coulomb	C	1	Coulomb	C
	Electric potential difference	V	1		
Capacitance	Farad	F	1	Farad	F
	(Electric) Resistance	Ω	1		
(Electric) Conductance	Ohm	Ω	1	Ohm	Ω
	Siemens	S	1		
Inductance	Henry	H	1	Henry	H
	Current	A	1		

● Inch-mm Conversion Table

1 inch=25.4mm

inch		0"	1"	2"	3"	4"	5"	6"	7"	8"
Fractional number	Decimal number									
	0		25.400	50.800	76.200	101.600	127.000	152.400	177.800	203.200
1 / 64"	0.015625	0.397	25.797	51.197	76.597	101.997	127.397	152.797	178.197	203.597
1 / 32"	0.031250	0.794	26.194	51.594	76.994	102.394	127.794	153.194	178.594	203.994
3 / 64"	0.046875	1.191	26.591	51.991	77.391	102.791	128.191	153.591	178.991	204.391
1 / 16"	0.062500	1.588	26.988	52.388	77.788	103.188	128.588	153.988	179.388	204.788
5 / 64"	0.078125	1.984	27.384	52.784	78.184	103.584	128.984	154.384	179.784	205.184
3 / 32"	0.093750	2.381	27.781	53.181	78.581	103.981	129.381	154.781	180.181	205.581
7 / 64"	0.109375	2.778	28.178	53.578	78.978	104.378	129.778	155.178	180.578	205.978
1 / 8"	0.125000	3.175	28.575	53.975	79.375	104.775	130.175	155.575	180.975	206.375
9 / 64"	0.140625	3.572	28.972	54.372	79.772	105.172	130.572	155.972	181.372	206.772
5 / 32"	0.156250	3.969	29.369	54.769	80.169	105.569	130.969	156.369	181.769	207.169
11 / 64"	0.171875	4.366	29.766	55.166	80.566	105.966	131.366	156.766	182.166	207.566
3 / 16"	0.187500	4.762	30.162	55.562	80.962	106.362	131.762	157.162	182.562	207.962
13 / 64"	0.203125	5.159	30.559	55.959	81.359	106.759	132.159	157.559	182.959	208.359
7 / 32"	0.218750	5.556	30.956	56.356	81.756	107.156	132.556	157.956	183.356	208.756
15 / 64"	0.234375	5.953	31.353	56.753	82.153	107.553	132.953	158.353	183.753	209.153
1 / 4"	0.250000	6.350	31.750	57.150	82.550	107.950	133.350	158.750	184.150	209.550
17 / 64"	0.265625	6.747	32.147	57.547	82.947	108.347	133.747	159.147	184.547	209.947
9 / 32"	0.281250	7.144	32.544	57.944	83.344	108.744	134.144	159.544	184.944	210.344
19 / 64"	0.296875	7.541	32.941	58.341	83.741	109.141	134.541	159.941	185.341	210.741
5 / 16"	0.312500	7.938	33.338	58.738	84.138	109.538	134.938	160.338	185.738	211.138
21 / 64"	0.328125	8.334	33.734	59.134	84.534	109.934	135.334	160.734	186.134	211.534
11 / 32"	0.343750	8.731	34.131	59.531	84.931	110.331	135.731	161.131	186.531	211.931
23 / 64"	0.359375	9.128	34.528	59.928	85.328	110.728	136.128	161.528	186.928	212.328
3 / 8"	0.375000	9.525	34.925	60.325	85.725	111.125	136.525	161.925	187.325	212.725
25 / 64"	0.390625	9.922	35.322	60.722	86.122	111.522	136.922	162.322	187.722	213.122
13 / 32"	0.406250	10.319	35.719	61.119	86.519	111.919	137.319	162.719	188.119	213.519
27 / 64"	0.421875	10.716	36.116	61.516	86.916	112.316	137.716	163.116	188.516	213.916
7 / 16"	0.437500	11.112	36.512	61.912	87.312	112.712	138.112	163.512	188.912	214.312
29 / 64"	0.453125	11.509	36.909	62.309	87.709	113.109	138.509	163.909	189.309	214.709
15 / 32"	0.468750	11.906	37.306	62.706	88.106	113.506	138.906	164.306	189.706	215.106
31 / 64"	0.484375	12.303	37.703	63.103	88.503	113.903	139.303	164.703	190.103	215.503
1 / 2"	0.500000	12.700	38.100	63.500	88.900	114.300	139.700	165.100	190.500	215.900

1 inch=25.4mm

inch		0"	1"	2"	3"	4"	5"	6"	7"	8"
Fractional number	Decimal number									
33 / 64"	0.515625	13.097	38.497	63.897	89.297	114.697	140.097	165.497	190.897	216.297
17 / 32"	0.531250	13.494	38.894	64.294	89.694	115.094	140.494	165.894	191.294	216.694
35 / 64"	0.546875	13.891	39.291	64.691	90.091	115.491	140.891	166.291	191.691	217.091
9 / 16"	0.562500	14.288	39.688	65.088	90.488	115.888	141.288	166.688	192.088	217.488
37 / 64"	0.578125	14.684	40.084	65.484	90.884	116.284	141.684	167.084	192.484	217.884
19 / 32"	0.593750	15.081	40.481	65.881	91.281	116.681	142.081	167.481	192.881	218.281
39 / 64"	0.609375	15.478	40.878	66.278	91.678	117.078	142.478	167.878	193.278	218.678
5 / 8"	0.625000	15.875	41.275	66.675	92.075	117.475	142.875	168.275	193.675	219.075
41 / 64"	0.640625	16.272	41.672	67.072	92.472	117.872	143.272	168.672	194.072	219.472
21 / 32"	0.656250	16.669	42.069	67.469	92.869	118.269	143.669	169.069	194.469	219.869
43 / 64"	0.671875	17.066	42.466	67.866	93.266	118.666	144.066	169.466	194.866	220.266
11 / 16"	0.687500	17.462	42.862	68.262	93.662	119.062	144.462	169.862	195.262	220.662
45 / 64"	0.703125	17.859	43.259	68.659	94.059	119.459	144.859	170.259	195.659	221.059
23 / 32"	0.718750	18.256	43.656	69.056	94.456	119.856	145.256	170.656	196.056	221.456
47 / 64"	0.734375	18.653	44.053	69.453	94.853	120.253	145.653	171.053	196.453	221.853
3 / 4"	0.750000	19.050	44.450	69.850	95.250	120.650	146.050	171.450	196.850	222.250
49 / 64"	0.765625	19.447	44.847	70.247	95.647	121.047	146.447	171.847	197.247	222.647
25 / 32"	0.781250	19.844	45.244	70.644	96.044	121.444	146.844	172.244	197.644	223.044
51 / 64"	0.796875	20.241	45.641	71.041	96.441	121.841	147.241	172.641	198.041	223.441
13 / 16"	0.812500	20.638	46.038	71.438	96.838	122.238	147.638	173.038	198.438	223.838
53 / 64"	0.828125	21.034	46.434	71.834	97.234	122.634	148.034	173.434	198.834	224.234
27 / 32"	0.843750	21.431	46.831	72.231	97.631	123.031	148.431	173.831	199.231	224.631
55 / 64"	0.859375	21.828	47.228	72.628	98.028	123.428	148.828	174.228	199.628	225.028
7 / 8"	0.875000	22.225	47.625	73.025	98.425	123.825	149.225	174.625	200.025	225.425
57 / 64"	0.890625	22.622	48.022	73.422	98.822	124.222	149.622	175.022	200.422	225.822
29 / 32"	0.906250	23.019	48.419	73.819	99.219	124.619	150.019	175.419	200.819	226.219
59 / 64"	0.921875	23.416	48.816	74.216	99.616	125.016	150.416	175.816	201.216	226.616
15 / 16"	0.937500	23.812	49.212	74.612	100.012	125.412	150.812	176.212	201.612	227.012
61 / 64"	0.953125	24.209	49.609	75.009	100.409	125.809	151.209	176.609	202.009	227.409
31 / 32"	0.968750	24.606	50.006	75.406	100.806	126.206	151.606	177.006	202.406	227.806
63 / 64"	0.984375	25.003	50.403	75.803	101.203	126.603	152.003	177.403	202.803	228.203

● Hardness Conversion Table (Reference)

Rockwell C scale hardness Load 1471N HRC	Vickers hardness HV	Brinell hardness		Rockwell hardness		Shore hardness HS
		Standard ball	Tungsten Carbide ball	A scale	B scale	
				Load 588.4N Diamond circular cone	Load 980.7N Diameter 1/16in ball	
68	940	—	—	85.6	—	97
67	900	—	—	85.0	—	95
66	865	—	—	84.5	—	92
65	832	—	(739)	83.9	—	91
64	800	—	(722)	83.4	—	88
63	772	—	(705)	82.8	—	87
62	746	—	(688)	82.3	—	85
61	720	—	(670)	81.8	—	83
60	697	—	(654)	81.2	—	81
59	674	—	(634)	80.7	—	80
58	653	—	615	80.1	—	78
57	633	—	595	79.6	—	76
56	613	—	577	79.0	—	75
55	595	—	560	78.5	—	74
54	577	—	543	78.0	—	72
53	560	—	525	77.4	—	71
52	544	(500)	512	76.8	—	69
51	528	(487)	496	76.3	—	68
50	513	(475)	481	75.9	—	67
49	498	(464)	469	75.2	—	66
48	484	451	455	74.7	—	64
47	471	442	443	74.1	—	63
46	458	432	432	73.6	—	62
45	446	421	421	73.1	—	60
44	434	409	409	72.5	—	58
43	423	400	400	72.0	—	57
42	412	390	390	71.5	—	56
41	402	381	381	70.9	—	55
40	392	371	371	70.4	—	54
39	382	362	362	69.9	—	52

Rockwell C scale hardness Load 1471N HRC	Vickers hardness HV	Brinell hardness		Rockwell hardness		Shore hardness HS
		Standard ball	Tungsten Carbide ball	A scale	B scale	
				Load 588.4N Diamond circular cone	Load 980.7N Diameter 1/16in ball	
38	372	353	353	69.4	—	51
37	363	344	344	68.9	—	50
36	354	336	336	68.4	(109.0)	49
35	345	327	327	67.9	(108.5)	48
34	336	319	319	67.4	(108.0)	47
33	327	311	311	66.8	(107.5)	46
32	318	301	301	66.3	(107.0)	44
31	310	294	294	65.8	(106.0)	43
30	302	286	286	65.3	(105.5)	42
29	294	279	279	64.7	(104.5)	41
28	286	271	271	64.3	(104.0)	41
27	279	264	264	63.8	(103.0)	40
26	272	258	258	63.3	(102.5)	38
25	266	253	253	62.8	(101.5)	38
24	260	247	247	62.4	(101.0)	37
23	254	243	243	62.0	100.0	36
22	248	237	237	61.5	99.0	35
21	243	231	231	61.0	98.5	35
20	238	226	226	60.5	97.8	34
(18)	230	219	219	—	96.7	33
(16)	222	212	212	—	95.5	32
(14)	213	203	203	—	93.9	31
(12)	204	194	194	—	92.3	29
(10)	196	187	187	—	90.7	28
(8)	188	179	179	—	89.5	27
(6)	180	171	171	—	87.1	26
(4)	173	165	165	—	85.5	25
(2)	166	158	158	—	83.5	24
(0)	160	152	152	—	81.7	24

● Tolerances of Shaft Dimensions

Classification of diameter mm		b12		c12		d6		e6		e12		f5		f6		g5	
		Above	Below	H	L	H	L	H	L	H	L	H	L	H	L	H	L
—	3	−140	− 240	− 60	− 160	− 20	− 26	− 14	− 20	− 14	−114	− 6	−10	− 6	− 12	− 2	− 6
3	6	−140	− 260	− 70	− 190	− 30	− 38	− 20	− 28	− 20	−140	−10	−15	−10	− 18	− 4	− 9
6	10	−150	− 300	− 80	− 230	− 40	− 49	− 25	− 34	− 25	−175	−13	−19	−13	− 22	− 5	−11
10	18	−150	− 330	− 95	− 275	− 50	− 61	− 32	− 43	− 32	−212	−16	−24	−16	− 27	− 6	−14
18	30	−160	− 370	−110	− 320	− 65	− 78	− 40	− 53	− 40	−250	−20	−29	−20	− 33	− 7	−16
30	40	−170	− 420	−120	− 370	− 80	− 96	− 50	− 66	− 50	−300	−25	−36	−25	− 41	− 9	−20
40	50	−180	− 430	−130	− 380												
50	65	−190	− 490	−140	− 440	−100	−119	− 60	− 79	− 60	−360	−30	−43	−30	− 49	−10	−23
65	80	−200	− 500	−150	− 450												
80	100	−220	− 570	−170	− 520	−120	−142	− 72	− 94	− 72	−422	−36	−51	−36	− 58	−12	−27
100	120	−240	− 590	−180	− 530												
120	140	−260	− 660	−200	− 600												
140	160	−280	− 680	−210	− 610	−145	−170	− 85	−110	− 85	−485	−43	−61	−43	− 68	−14	−32
160	180	−310	− 710	−230	− 630												
180	200	−340	− 800	−240	− 700												
200	225	−380	− 840	−260	− 720	−170	−199	−100	−129	−100	−560	−50	−70	−50	− 79	−15	−35
225	250	−420	− 880	−280	− 740												
250	280	−480	−1000	−300	− 820	−190	−222	−110	−142	−110	−630	−56	−79	−56	− 88	−17	−40
280	315	−540	−1060	−330	− 850												
315	355	−600	−1170	−360	− 930	−210	−246	−125	−161	−125	−695	−62	−87	−62	− 98	−18	−43
355	400	−680	−1250	−400	− 970												
400	450	−760	−1390	−440	−1070	−230	−270	−135	−175	−135	−765	−68	−95	−68	−108	−20	−47
450	500	−840	−1470	−480	−1110												

Classification of diameter mm		h12		js5		j5		js6		j6		j7		k5		k6	
		H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L
—	3	0	−100	+ 2	− 2	+2	− 2	+ 3	− 3	+ 4	− 2	+ 6	− 4	+ 4	0	+ 6	0
3	6	0	−120	+ 2.5	− 2.5	+3	− 2	+ 4	− 4	+ 6	− 2	+ 8	− 4	+ 6	+1	+ 9	+1
6	10	0	−150	+ 3	− 3	+4	− 2	+ 4.5	− 4.5	+ 7	− 2	+10	− 5	+ 7	+1	+10	+1
10	18	0	−180	+ 4	− 4	+5	− 3	+ 5.5	− 5.5	+ 8	− 3	+12	− 6	+ 9	+1	+12	+1
18	30	0	−210	+ 4.5	− 4.5	+5	− 4	+ 6.5	− 6.5	+ 9	− 4	+13	− 8	+11	+2	+15	+2
30	40	0	−250	+ 5.5	− 5.5	+6	− 5	+ 8	− 8	+11	− 5	+15	−10	+13	+2	+18	+2
40	50	0	−300	+ 6.5	− 6.5	+6	− 7	+ 9.5	− 9.5	+12	− 7	+18	−12	+15	+2	+21	+2
50	65	0	−350	+ 7.5	− 7.5	+6	− 9	+11	−11	+13	− 9	+20	−15	+18	+3	+25	+3
65	80	0	−400	+ 9	− 9	+7	−11	+12.5	−12.5	+14	−11	+22	−18	+21	+3	+28	+3
80	100	0	−460	+10	−10	+7	−13	+14.5	−14.5	+16	−13	+25	−21	+24	+4	+33	+4
100	120	0	−520	+11.5	−11.5	+7	−16	+16	−16	+16	−16	+26	−26	+27	+4	+36	+4
120	140	0	−570	+12.5	−12.5	+7	−18	+18	−18	+18	−18	+29	−28	+29	+4	+40	+4
140	160	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
160	180	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
180	200	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
200	225	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
225	250	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
250	280	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
280	315	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
315	355	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
355	400	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
400	450	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
450	500	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5

unit: μm

g6		h5		h6		h7		h8		h9		h10		h11		Classification of diameter mm	
		H	L	H	L	H	L	H	L	H	L	H	L	H	L		
−2	−8	0	−4	0	−6	0	−10	0	−14	0	−25	0	−40	0	−60	—	3
−4	−12	0	−5	0	−8	0	−12	0	−18	0	−30	0	−48	0	−75	3	6
−5	−14	0	−6	0	−9	0	−15	0	−22	0	−36	0	−58	0	−90	6	10
−6	−17	0	−8	0	−11	0	−18	0	−27	0	−43	0	−70	0	−110	10	18
−7	−20	0	−9	0	−13	0	−21	0	−33	0	−52	0	−84	0	−130	18	30
−9	−25	0	−11	0	−16	0	−25	0	−39	0	−62	0	−100	0	−160	30	40
−10	−29	0	−13	0	−19	0	−30	0	−46	0	−74	0	−120	0	−190	40	50
−12	−34	0	−15	0	−22	0	−35	0	−54	0	−87	0	−140	0	−220	50	65
−14	−39	0	−18	0	−25	0	−40	0	−63	0	−100	0	−160	0	−250	65	80
−15	−44	0	−20	0	−29	0	−46	0	−72	0	−115	0	−185	0	−290	80	100
−17	−49	0	−23	0	−32	0	−52	0	−81	0	−130	0	−210	0	−320	100	120
−18	−54	0	−25	0	−36	0	−57	0	−89	0	−140	0	−230	0	−360	120	140
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	140	160
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	160	180
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	180	200
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	200	225
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	225	250
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	250	280
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	280	315
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	315	355
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	355	400
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	400	450
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	450	500

unit: μm

m5		m6		n5		n6		p6		Classification of diameter mm	
H	L	H	L	H	L	H	L	H	L	Above	Below
+ 6	+ 2	+ 8	+ 2	+ 8	+ 4	+10	+ 4	+ 12	+ 6	—	3
+ 9	+ 4	+12	+ 4	+13	+ 8	+16	+ 8	+ 20	+12	3	6
+12	+ 6	+15	+ 6	+16	+10	+19	+10	+ 24	+15	6	10
+15	+ 7	+18	+ 7	+20	+12	+23	+12	+ 29	+18	10	18
+17	+ 8	+21	+ 8	+24	+15	+28	+15	+ 35	+22	18	30
+20	+ 9	+25	+ 9	+28	+17	+33	+17	+ 42	+26	30 40	40 50
+24	+11	+30	+11	+33	+20	+39	+20	+ 51	+32	50 65	65 80
+28	+13	+35	+13	+38	+23	+45	+23	+ 59	+37	80 100	100 120
+33	+15	+40	+15	+45	+27	+52	+27	+ 68	+43	120 140 160	140 160 180
+37	+17	+46	+17	+51	+31	+60	+31	+ 79	+50	180 200 225	200 225 250
+43	+20	+52	+20	+57	+34	+66	+34	+ 88	+56	250 280	280 315
+46	+21	+57	+21	+62	+37	+73	+37	+ 98	+62	315 355	355 400
+50	+23	+63	+23	+67	+40	+80	+40	+108	+68	400 450	450 500

● Tolerances of Housing Hole Dimensions

Classification of diameter mm		B12		E7		E11		E12		F6		F7		G6		G7	
		Above	Below	H	L	H	L	H	L	H	L	H	L	H	L	H	L
—	3			+ 240	+140	+ 24	+ 14	+ 74	+ 14	+114	+ 14	+ 12	+ 6	+ 16	+ 6	+ 8	+ 2
3	6			+ 260	+140	+ 32	+ 20	+ 95	+ 20	+140	+ 20	+ 18	+10	+ 22	+10	+12	+ 4
6	10			+ 300	+150	+ 40	+ 25	+115	+ 25	+175	+ 25	+ 22	+13	+ 28	+13	+14	+ 5
10	18			+ 330	+150	+ 50	+ 32	+142	+ 32	+212	+ 32	+ 27	+16	+ 34	+16	+17	+ 6
18	30			+ 370	+160	+ 61	+ 40	+170	+ 40	+250	+ 40	+ 33	+20	+ 41	+20	+20	+ 7
30	40			+ 420	+170	+ 75	+ 50	+210	+ 50	+300	+ 50	+ 41	+25	+ 50	+25	+25	+ 9
40	50			+ 430	+180												
50	65			+ 490	+190	+ 90	+ 60	+250	+ 60	+360	+ 60	+ 49	+30	+ 60	+30	+29	+10
65	80			+ 500	+200												
80	100			+ 570	+220	+107	+ 72	+292	+ 72	+422	+ 72	+ 58	+36	+ 71	+36	+34	+12
100	120			+ 590	+240												
120	140			+ 660	+260												
140	160			+ 680	+280	+125	+ 85	+335	+ 85	+485	+ 85	+ 68	+43	+ 83	+43	+39	+14
160	180			+ 710	+310												
180	200			+ 800	+340												
200	225			+ 840	+380	+146	+100	+390	+100	+560	+100	+ 79	+50	+ 96	+50	+44	+15
225	250			+ 880	+420												
250	280			+1000	+480	+162	+110	+430	+110	+630	+110	+ 88	+56	+108	+56	+49	+17
280	315			+1060	+540												
315	355			+1170	+600	+182	+125	+485	+125	+695	+125	+ 98	+62	+119	+62	+54	+18
355	400			+1250	+680												
400	450			+1390	+760	+198	+135	+535	+135	+765	+135	+108	+68	+131	+68	+60	+20
450	500			+1470	+840												

Classification of diameter mm		JS7		J7		K5		K6		K7		M6		M7		N6	
		Above	Below	H	L	H	L	H	L	H	L	H	L	H	L	H	L
—	3			+ 5	− 5	+ 4	− 6	0	− 4	0	− 6	0	− 10	− 2	− 8	−2	−12
3	6			+ 6	− 6	+ 6	− 6	0	− 5	+2	− 6	+ 3	− 9	− 1	− 9	0	−12
6	10			+ 7	− 7	+ 8	− 7	+1	− 5	+2	− 7	+ 5	−10	− 3	−12	0	−15
10	18			+ 9	− 9	+10	− 8	+2	− 6	+2	− 9	+ 6	−12	− 4	−15	0	−18
18	30			+10	−10	+12	− 9	+1	− 8	+2	−11	+ 6	−15	− 4	−17	0	−21
30	40			+12	−12	+14	−11	+2	− 9	+3	−13	+ 7	−18	− 4	−20	0	−25
40	50																
50	65			+15	−15	+18	−12	+3	−10	+4	−15	+ 9	−21	− 5	−24	0	−30
65	80																
80	100			+17	−17	+22	−13	+2	−13	+4	−18	+10	−25	− 6	−28	0	−35
100	120																
120	140			+20	−20	+26	−14	+3	−15	+4	−21	+12	−28	− 8	−33	0	−40
140	160																
160	180																
180	200			+23	−23	+30	−16	+2	−18	+5	−24	+13	−33	− 8	−37	0	−46
200	225																
225	250																
250	280			+26	−26	+36	−16	+3	−20	+5	−27	+16	−36	− 9	−41	0	−52
280	315																
315	355			+28	−28	+39	−18	+3	−22	+7	−29	+17	−40	−10	−46	0	−57
355	400																
400	450			+31	−31	+43	−20	+2	−25	+8	−32	+18	−45	−10	−50	0	−63
450	500																

unit: μm

H6		H7		H8		H9		H10		H11		JS6		J6		Classification of diameter mm	
		H	L	H	L	H	L	H	L	H	L	H	L	H	L		
+ 6	0	+10	0	+14	0	+ 25	0	+ 40	0	+ 60	0	+ 3	− 3	+ 2	−4	—	3
+ 8	0	+12	0	+18	0	+ 30	0	+ 48	0	+ 75	0	+ 4	− 4	+ 5	−3	3	6
+ 9	0	+15	0	+22	0	+ 36	0	+ 58	0	+ 90	0	+ 4.5	− 4.5	+ 5	−4	6	10
+11	0	+18	0	+27	0	+ 43	0	+ 70	0	+110	0	+ 5.5	− 5.5	+ 6	−5	10	18
+13	0	+21	0	+33	0	+ 52	0	+ 84	0	+130	0	+ 6.5	− 6.5	+ 8	−5	18	30
+16	0	+25	0	+39	0	+ 62	0	+100	0	+160	0	+ 8	− 8	+10	−6	30	40
																40	50
+19	0	+30	0	+46	0	+ 74	0	+120	0	+190	0	+ 9.5	− 9.5	+13	−6	50	65
																65	80
+22	0	+35	0	+54	0	+ 87	0	+140	0	+220	0	+11	−11	+16	−6	80	100
																100	120
+25	0	+40	0	+63	0	+100	0	+160	0	+250	0	+12.5	−12.5	+18	−7	120	140
																140	160
																160	180
+29	0	+46	0	+72	0	+115	0	+185	0	+290	0	+14.5	−14.5	+22	−7	180	200
																200	225
																225	250
+32	0	+52	0	+81	0	+130	0	+210	0	+320	0	+16	−16	+25	−7	250	280
																280	315
+36	0	+57	0	+89	0	+140	0	+230	0	+360	0	+18	−18	+29	−7	315	355
																355	400
+40	0	+63	0	+97	0	+155	0	+250	0	+400	0	+20	−20	+33	−7	400	450
																450	500

unit: μm

N7		P6		P7		R7		S7		Classification of diameter mm	
		H	L	H	L	H	L	H	L		
− 4	−14	− 6	−12	− 6	− 16	− 10	− 20	− 14	− 24	—	3
− 4	−16	− 9	−17	− 8	− 20	− 11	− 23	− 15	− 27	3	6
− 4	−19	−12	−21	− 9	− 24	− 13	− 28	− 17	− 32	6	10
− 5	−23	−15	−26	−11	− 29	− 16	− 34	− 21	− 39	10	18
− 7	−28	−18	−31	−14	− 35	− 20	− 41	− 27	− 48	18	30
− 8	−33	−21	−37	−17	− 42	− 25	− 50	− 34	− 59	30	40
										40	50
− 9	−39	−26	−45	−21	− 51	− 30	− 60	− 42	− 72	50	65
										65	80
−10	−45	−30	−52	−24	− 59	− 38	− 73	− 58	− 93	80	100
										100	120
−12	−52	−36	−61	−28	− 68	− 48	− 88	− 77	−117	120	140
										140	160
										160	180
−14	−60	−41	−70	−33	− 79	− 60	−106	−105	−151	180	200
										200	225
										225	250
−14	−66	−47	−79	−36	− 88	− 74	−126	−138	−190	250	280
										280	315
−16	−73	−51	−87	−41	− 98	− 87	−144	−169	−226	315	355
										355	400
−17	−80	−55	−95	−45	−108	−103	−166	−209	−272	400	450
										450	500