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**ORDER EXAMPLE**


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**Example of how to place an order for rails and cages:**

10 guides M4020x300-T15-Q10-E2-US  
 10 guides V4020x500-T03-Q10-US  
 10 cages E-HW15x300-AL-G2

**Example of ordering a rail set:**

Required for pairing when using different rail types in the same slide.  
 The set is packaged in a single package.  
 20 sets M/V/ML5025x300-Q6  
 Composed of:

- 1 M5025x300-T15-Q6-2SX
- 1 ML6025x300-T15L-Q6-2SX
- 2 V5025x300-T15-Q6-US
- 2 E-HW16 x 226-AI-G2
- 4 EV5025

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## 1.1 UNITS AND DEFINITIONS

<b>B</b>	<b>mm</b>	Guideway width	<b>L</b>	<b>mm</b>	Guideway length
<b>B1</b>	<b>mm</b>	Cage width	<b>L</b>	<b>10<sup>5</sup>m</b>	Nominal rating life
<b>b</b>	<b>mm</b>	Distance between guidance system centres	<b>L1</b>	<b>mm</b>	Distance between the first hole and the start of the guideway
<b>b1</b>	<b>mm</b>	Distance between rear guideway surfaces	<b>L1</b>	<b>mm</b>	Distance between the first or last pocket centre and the end of the cage
<b>C</b>	<b>N</b>	Basic dynamic load rating for cage length of 100 mm	<b>L2</b>	<b>mm</b>	Distance between the last hole and the end of the guideway
<b>C<sub>w</sub></b>	<b>N</b>	Effective dynamic load rating	<b>L1, L2<sub>min</sub></b>	<b>mm</b>	Minimum value for L1 and L2
<b>C<sub>we</sub></b>	<b>N</b>	Corrected effective dynamic load rating	<b>LA</b>	<b>mm</b>	Hole distance in guideways
<b>C<sub>L</sub></b>	<b>N/mm</b>	Rigidity of the flat cage guidance system	<b>LA</b>	<b>mm</b>	Spacing distance in flat cages
<b>C<sub>0</sub></b>	<b>N</b>	Basic static load rating for cage length of 100 mm	<b>L<sub>h</sub></b>	<b>h</b>	Nominal rating life in operating hours
<b>C<sub>0we</sub></b>	<b>N</b>	Corrected effective static load rating	<b>L<sub>k</sub></b>	<b>mm</b>	Cage length
<b>C<sub>0w</sub></b>	<b>N</b>	Effective static load rating	<b>L<sub>R</sub></b>	<b>mm</b>	Guideway length with running surface for the wiper
<b>D<sub>w</sub></b>	<b>mm</b>	Ball diameter	<b>n</b>	-	Maximum possible number of hole distances LA
<b>e</b>	<b>mm</b>	Eccentricity of the load	<b>n<sub>osz</sub></b>	<b>min<sup>-1</sup></b>	Number of double strokes per minute
<b>f<sub>H</sub></b>	-	Dynamic hardness factor	<b>p</b>	-	Rating life exponent
<b>f<sub>H0</sub></b>	-	Static hardness factor	<b>p</b>	<b>N/mm<sup>2</sup></b>	Contact pressure for sliding layer
<b>f<sub>α</sub></b>	-	Dynamic load direction factor	<b>P</b>	<b>N</b>	Dynamic equivalent load
<b>f<sub>α0</sub></b>	-	Static load direction factor	<b>P<sub>0</sub></b>	<b>N</b>	Static equivalent load
<b>F</b>	<b>N</b>	Operating load, guide loading	<b>q<sub>i</sub></b>	<b>%</b>	Proportion of total duration
<b>F<sub>i</sub></b>	<b>N</b>	Variable load	<b>RS</b>	<b>N</b>	Damping force in direction of movement
<b>F<sub>R</sub></b>	<b>N</b>	Displacement resistance	<b>S<sub>0</sub></b>	-	Static load safety factor
<b>F<sub>R0</sub></b>	<b>N</b>	F <sub>R</sub> , lubricant friction percentage	<b>t</b>	<b>mm</b>	Depth of thread in T03 holes
<b>F<sub>R1</sub></b>	<b>N</b>	F <sub>R</sub> , load-dependent rolling friction percentage	<b>v<sub>i</sub></b>	<b>m/min</b>	Variable speed
<b>F<sub>RA</sub></b>	<b>N</b>	Displacement resistance, wiper percentage	<b>v̄</b>	<b>m/min</b>	Dynamic equivalent speed
<b>F<sub>RV</sub></b>	<b>N</b>	Carriage displacement resistance, preloaded	<b>x</b>	-	Number of holes
<b>F<sub>w</sub></b>	<b>N</b>	Limiting load for effective cage length	<b>Z</b>	-	Number of rolling elements per row
<b>H</b>	<b>mm</b>	Distance from extreme stroke positions	<b>α</b>	<b>°</b>	Load direction angle deviating from main load direction
<b>k<sub>F</sub></b>	-	Dynamic load factor	<b>δ</b>	<b>μm</b>	Elastic deformation at contact points
<b>k<sub>0F</sub></b>	-	Static load factor	<b>μ</b>	-	Friction coefficient
<b>K</b>	-	Type factor for determination of rigidity	<b>ν</b>	<b>mm<sup>2</sup>s<sup>-1</sup></b>	Kinematic viscosity
			<b>Δh</b>	<b>μm</b>	Permissible height variation

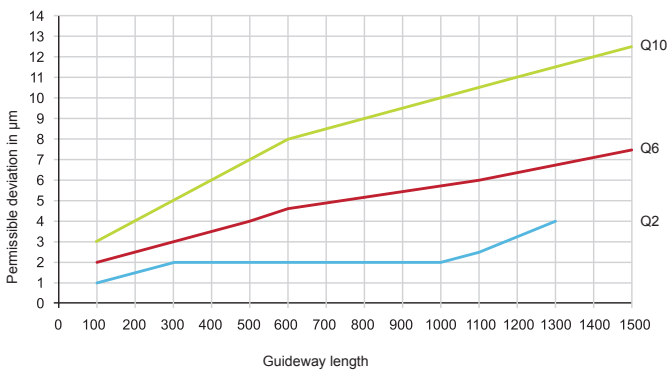
## 1.2 PRECISION AND TOLERANCES

### 1.2.1 QUALITIES

The raceways and locating surfaces are precision-ground.

The guideways are supplied in 3 qualities (parallelism tolerance of the raceways to the reference sides of the guideway in relation to a defined length).

- Q10: normal quality for general machine construction
- Q6: precise quality for machine tool construction
- Q2: particularly precise quality for exceptionally demanding structures



### 1.2.2 PROFILE TOLERANCES

See product chapter

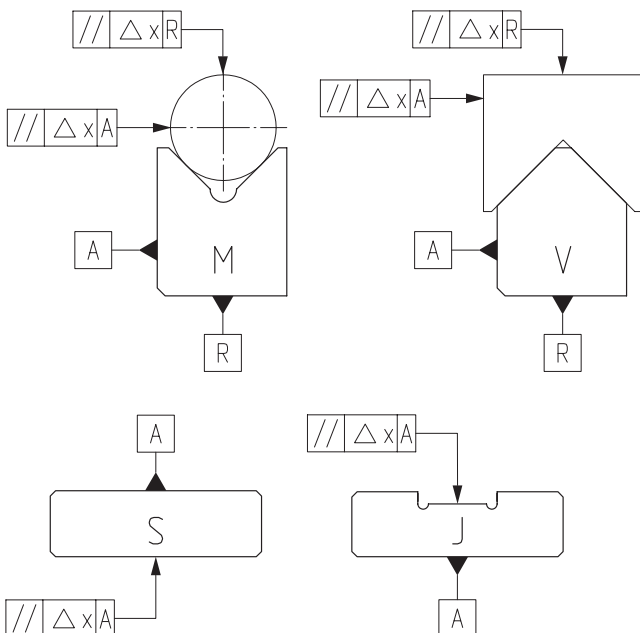
### 1.2.3 LENGTHS, HOLE DISTANCES

Length: the length tolerance is defined using the formula  $\pm [0.2+(0.0012 \cdot \text{length } L)]$ .

Guideways which exceed the maximum length indicated (see “normal lengths” table) are manufactured in several sections. These sections are matched precisely. It is important not to interchange the guideways in order to maintain the tolerance during assembly.

**Hole distances:** the tolerance of the hole distances is calculated to ensure that guideways can be assembled on a pre-drilled hole pattern up to the maximum normal length. The tolerance is measured between the first and last guideway hole and is distributed evenly over the length.

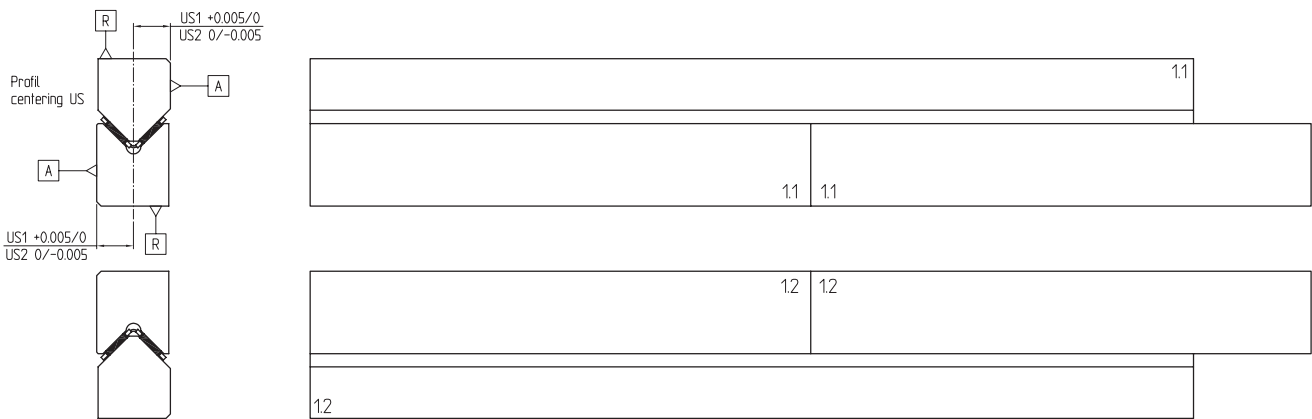
For guideways which exceed the maximum normal length, the suffix “P” is required in order to maintain the corresponding tolerance.



1.2.4 MATCHING

Guideways of the same design (same order reference) are manufactured, labelled and packed in pairs. Paired matching is based on the distance between the centre of the profile and the mounting surface "A".

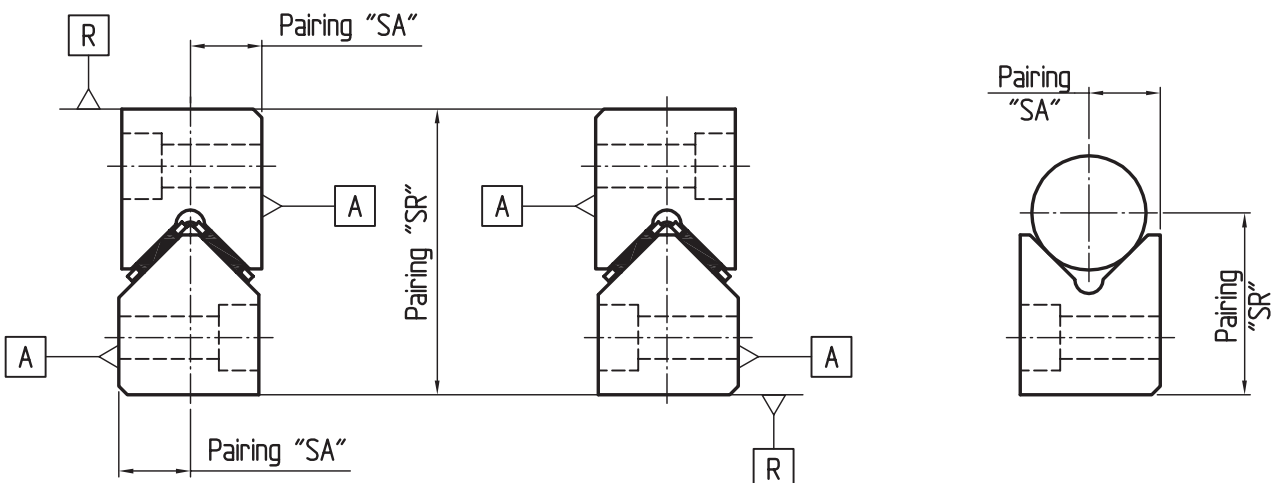
Standard matching (US1/US2) allows parts to be exchanged whilst maintaining a very narrow tolerance. In the highest tolerance category or at the customer's request, the guideways are matched and labelled by more narrow tolerances.



For guideways with different order references which still have to be matched in pairs, the suffix "X" has to be added to the order references, e.g.

- 1M + 1ML = 2SX or
- 1M + 1V + 1J + 1S = 4SRX or
- 1V...T15 + 1V...T03 = 2SX

Matching possibilities:



Paired matching code	Number of guideways matched together	In relation to reference side
2SA	2	Reference side A
3SA	3	Reference side A
4SA	4	Reference side A
etc...	Number of guideways	Reference side A
2SR	2	Reference side R
3SR	3	Reference side R
4SR	4	Reference side R
etc...	Number of guideways	Reference side R
2SAR	2	Reference sides A + R
3SAR	3	Reference sides A + R
4SAR	4	Reference sides A + R
etc...	Number of guideways	Reference sides A + R

### 1.2.5 STRAIGHTNESS

Straightness as well as parallelism is checked in the factory (tolerances according to DIN 644).

Straightness variances can be balanced out by tightening against the locating surface during assembly.

### 1.2.6 ROLLING ELEMENTS

Flat cage assemblies comprise needle or cylindrical rollers with a diameter tolerance of 2 µm and a geometrical accuracy of 1 µm.

For particularly challenging requirements, especially for guideways with a quality level of 2, specially designed needle or cylindrical rollers can be supplied with a diameter tolerance of 1 µm and a geometrical accuracy of 0.5 µm.

The diameter tolerance amounts to 1 µm and the geometrical accuracy 0.13 µm for ball bearings.

See table (page 74), in chapter 8 on flat cage assemblies.

## 1.3 APPLICATION FEATURES

### 1.3.1 CHOICE OF ARRANGEMENT TYPE

#### Closed layout M/V

This layout can carry loads and moments in any direction, can be adapted to any operating position and can be preloaded (preloading page 32).

It is a locating/locating bearing and consists of two M / ML and two V guideways with the corresponding angled flat cage assemblies.

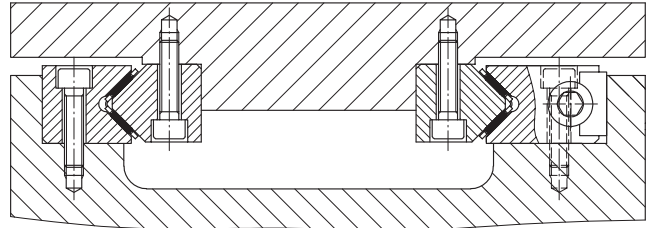


Figure 1. Closed layout M/V

#### Open layout

This layout is extremely assembly-friendly and is mainly used for applications with loads acting centrally or vertically.

It is a locating/non-locating bearing and consists of M and V guideways with the corresponding angled flat cage assembly and J and S guideways with the corresponding flat cage assembly.

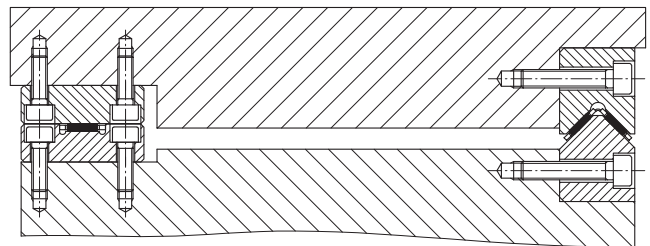


Figure 2. Open layout M/V, J/S

#### Closed layout LUE

This layout can carry loads and moments in any direction in response to the most demanding precision requirements. The system is preloaded by components which have been adjusted against one another in terms of dimensions.

The subdivision into locating and non-locating bearings prevents the system from becoming distorted by thermal expansion. The guidance system consists of M and V guideways, J and S guideways, LU counterstays, angled flat and flat cage assemblies.

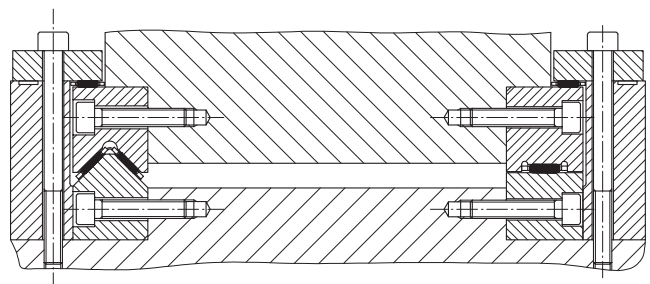


Figure 3. Closed layout LUE

1.3.2 DETERMINATION OF GUIDEWAY CAGE LENGTHS

The rigidity and load carrying capacity of the guidance system are determined by the size and length of the flat cage assembly ( $L_K$ ). The load bearing capacity and load carrying capacity increase for moments along the longitudinal axis (rolling) in proportion to the cage length whilst the permissible moments along the vertical axis (yawing) and the diagonal axis (pitching) increase in square with the cage length.

Layout principles:

- The cage assembly always travels half of the stroke of the moving guideway
- The entire length of the cage assembly must always remain between the two guideways
- Wipers must always remain on the raceways

Recommendations for minimum cage lengths dependent on the stroke:

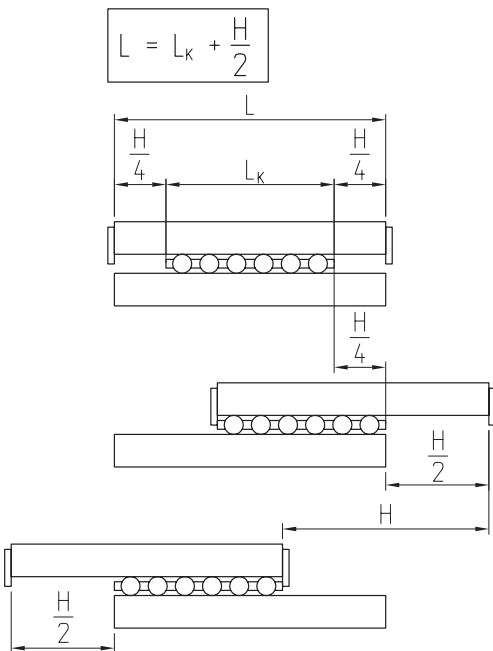
- $L_K \geq 1.5 \cdot H$  for open layout in order to maintain the operation limit (figure 12, page 24)
- $L_K \geq H$  for closed layout

**H** mm | distance from extreme stroke positions

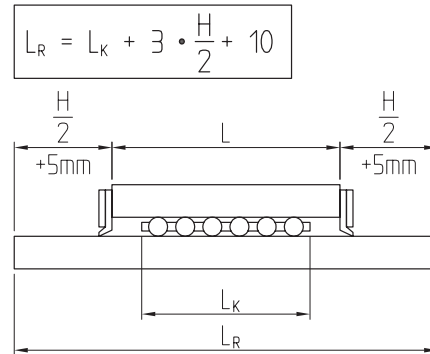
**A) Calculation of guideway lengths L, L<sub>R</sub>**

With preset cage length and stroke:

Guidance systems without wipers



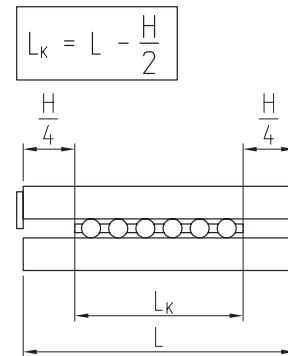
Guidance systems with wipers



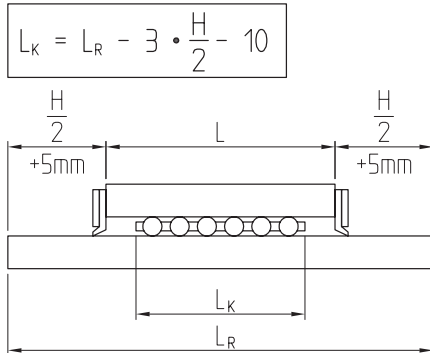
**B) Calculation of cage length L<sub>K</sub>**

With preset guideway lengths and stroke:

Guidance systems without wipers



Guidance systems with wipers:



The necessary cage size can be selected on the basis of load and rigidity parameters.

**Special length ratios:**

If the lengths are configured according to the equations above, the flat cage assembly will be in every stroke position between the raceways.

In order to achieve the maximum load carrying capacity or a significant stroke, the lengths can be configured under normal operating conditions in such a way that the flat cage assembly extends beyond the ends of the guideways. Raceway lead areas should be provided in this case (suffix E2).

**1.3.3 HOLE TYPES AND HOLE PATTERNS**

Guideways are attached with screws. EGIS guideways are supplied with 5 hole types (figure 4).

EGIS guideways of standard lengths in the M and V ranges are hardened and pre-ground with T15 sink holes. By adding ESM insert nuts, these guideways can be attached in the same manner as with a threaded hole (T03, figure 5).

The insert nuts must be ordered separately and stuck into the counterbores (T13, accessories, page 87).

The guide rails can be supplied with smooth holes T10 or threaded holes T03.

Some guide rails can be supplied with hole type T1503, which allows the rail to be fastened on both sides. Either as T15 or as T03 or T13.

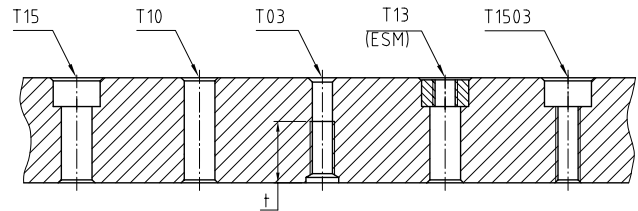


Figure 4. Hole types

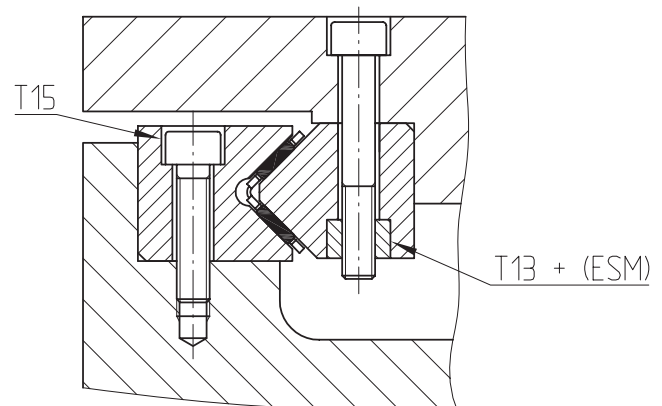


Figure 5. Attachment with hole type T13

With no particular specifications, the hole distances L1 and L2 at both ends of the guideways are of the same size and dependent on the guideway length (symmetrical hole pattern, figure 6).  
 Guideways with non-symmetrical hole patterns may also be supplied on request.  
 In this case the following values must apply:  $L1 \geq L1_{min}$  and  $L2 \geq L2_{min}$ .

△ Particular attention should be paid to the position of the L1 distance. For the definition of the position of L1 see figure 7.  
 Suffix LA (L1/L2)

Determining the hole patterns

Number of spacing distances

$$n = \frac{(L - 2 \cdot L1_{min})}{LA} \text{ whole number}$$

Distances L1 and L2

$$L1 + L2 = L - n \cdot LA$$

Guideways with symmetrical hole pattern

$$L1 = L2 = (L - n \cdot LA) / 2$$

Number of holes

$$x = n + 1$$

<b>L</b>	<b>mm</b>	Length of guideway
<b>LA</b>	<b>mm</b>	Hole distance
<b>L1, L2</b>	<b>mm</b>	Distance between the start or end of the guideway and the next hole
<b>L1<sub>min</sub>, L2<sub>min</sub></b>	<b>mm</b>	Minimum value for L1 and L2 (Tables dimensions)
<b>n</b>	-	Maximum possible spacing distances
<b>x</b>	-	Number of holes

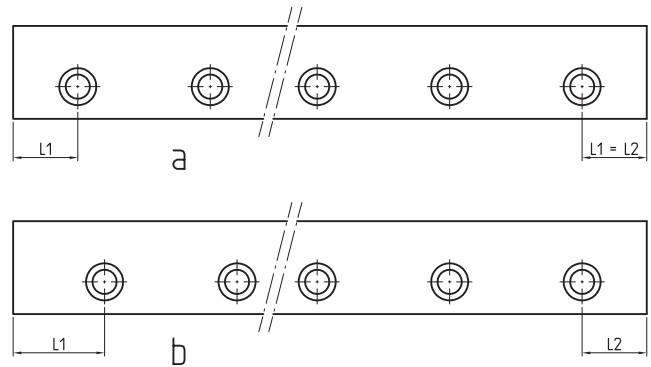


Figure 6. Symmetrical (a) and non-symmetrical (b) hole pattern with a series of holes

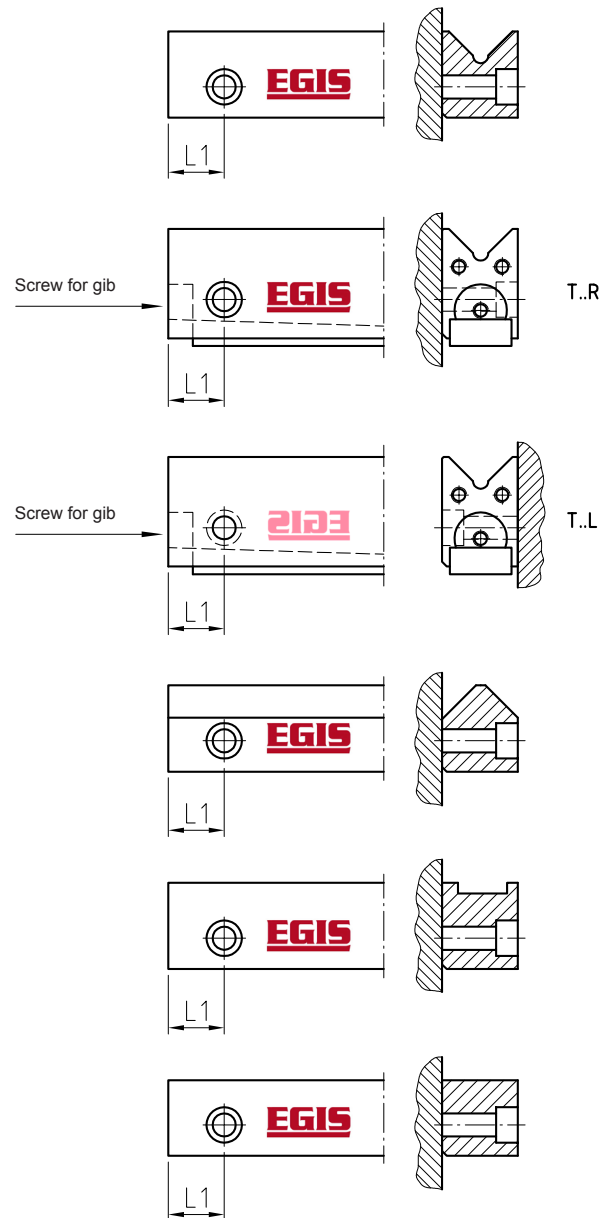


Figure 7. Position of distance between first hole and beginning of guideway L1

### 1.3.4 END PIECES AND WIPERS

End pieces or end pieces with wipers hold the cage assembly in place correctly in the final stroke positions. Two end pieces need to be mounted for each cage. If this is not possible, parts of the connecting structure should be used to assume the function of the end pieces.

- △ End pieces or wipers must not be used to limit the stroke.
- △ End pieces or wipers must not be allowed to cross over (figure 8)

In specific application scenarios, e.g. with rapid accelerations, extreme loads in the final stroke positions or in the case of alternating partial stroke which nevertheless remain constant over long periods, the cage positioning may no longer be guaranteed with normal end pieces. In such cases, it is possible when wipers are used to assemble additional end pieces before the wipers or to subject the cage to positive control by an integrated gear/toothed rack unit as an optimum solution (MVZ series, page 52).

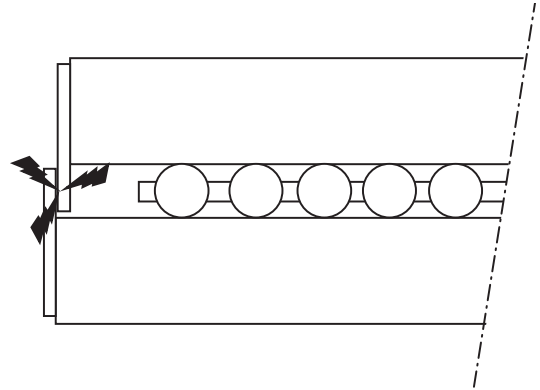


Figure 8. Incorrectly assembled end pieces or wipers

### 1.3.5 LOAD RATING, LOAD CARRYING CAPACITY

The dynamic and static load ratings are used as a reference for the layout of a flat cage guidance system. The load ratings for linear guidance systems without recirculating rolling elements are defined according to the ISO 14728 international standard.

#### 1.3.5.1 BASIC STATIC LOAD RATING

The basic static load ratings  $C_0$  are the loads which bring a permanent deformation of the raceways and rolling elements in a ten thousandth of the rolling element diameter.

##### Static load safety factor

The static load safety factor  $S_0$  is the security in relation to the permanent deformation in the rolling contact.

$$S_0 = \frac{C_{0w}}{P_0}$$

$S_0$		Static load safety factor
$C_{0w}$	<b>N</b>	Effective static load rating (page 22)
$P_0$	<b>N</b>	Maximum static equivalent load

△ Particular attention should be paid to the load safety factor.

According to ISO 14728, the static safety  $S_0 = C_0/P_0$  must not fall below the value of 2.

If strict requirements apply in terms of the running accuracy and smoothness, the static load safety factor should not fall below  $S_0 = 3$ .

#### 1.3.5.2 STATIC LOAD CARRYING CAPACITY

The permissible static load for a flat case guidance system is limited by the following characteristics:

- Basic static load rating of the flat cage assemblies: recommendations for  $S_0$  should be observed.
- Load carrying capacity of the raceways: required hardness HRC 58 min.
- Load carrying capacity of the connecting structure: the connecting structure is generally configured with a high degree of rigidity and therefore sufficient strength.
- Load carrying capacity of the screw connection: the layout of the guideway attachment is based on the screw strength 8.8 and the corresponding tightening torque taking the standard materials for the connecting structure into account. Screws of this level of strength allow for the transferral of loads whilst scarcely affecting the precision of the guidance system.

When screws of a higher strength category are used, the tightening torque according to the strength category 8.8 should not be exceeded in the interest of accuracy (exception: LUE system counterstay, see page 71).

△ It is important to check the screw connection where  $S_0 < 3$  when tensile and / or moment loads are predominant.

## LOAD RATING, LOAD CARRYING CAPACITY

## 1.3.5.3 BASIC DYNAMIC LOAD RATING

The basis for the basic dynamic load rating  $C$  is the nominal rating life of 100,000 m displacement distance obtained or exceeded with a reliability of 90%.

## 1.3.5.4 DYNAMIC LOAD CARRYING CAPACITY AND RATING LIFE

The dynamic load carrying capacity is determined by the fatigue behaviour of the bearing components. The fatigue period (the rating life in hours) is obtained from the load and the movement speed of the guidance system as well as the statistical probability of damage occurring.

## Nominal rating life

$$L = \left( \frac{C_w}{P} \right)^p$$

$$L_h = \frac{8.33 \cdot 10^5}{H \cdot n_{osz}} \cdot \left( \frac{C_w}{P} \right)^p$$

$$L_h = \frac{1666}{\bar{v}} \cdot \left( \frac{C_w}{P} \right)^p$$

<b>L</b>	<b>10<sup>5</sup>m</b>	Nominal rating life
<b>L<sub>h</sub></b>	<b>h</b>	Nominal rating life in operating hours
<b>C<sub>w</sub></b>	<b>N</b>	Effective dynamic load rating (p. 24)
<b>P</b>	<b>N</b>	Dynamic equivalent load
<b>p</b>	<b>-</b>	Rating life exponent

For flat cage guidance systems with rollers:  $p=10/3$   
 For flat cage guidance systems with balls:  $p=3$

<b>H</b>	<b>mm</b>	Distance from extreme stroke positions
<b>n<sub>osz</sub></b>	<b>min<sup>-1</sup></b>	Number of double strokes per minute
<b><math>\bar{v}</math></b>	<b>m/min</b>	Dynamic equivalent speed

△ According to ISO 14728, the dynamic equivalent load must not exceed the value  $P = 0.5 \cdot C_w$ .

LOAD RATING, LOAD CARRYING CAPACITY

Equivalent load and speed

The life calculation equation requires a constant load and speed. If this is not the case, equivalent operating values may be used for the calculation. (ISO 281 standard)

General dynamic equivalent load

$$P = \sqrt[p]{\left(\int_0^T |v(t) \cdot F^p(t)| dt\right) / \left(\int_0^T |v(t)| dt\right)}$$

General dynamic equivalent speed

$$\bar{v} = \frac{1}{T} \int_0^T |v(t)| dt$$

Gradually alternating load

$$P = \sqrt[p]{\frac{q_1 \cdot F_1^p + q_2 \cdot F_2^p + \dots + q_z \cdot F_z^p}{100}}$$

Gradually alternating speed

$$\bar{v} = \frac{q_1 \cdot v_1 + q_2 \cdot v_2 + \dots + q_z \cdot v_z}{100}$$

Gradually alternating load and gradually alternating speed

$$P = \sqrt[p]{\frac{q_1 \cdot v_1 + F_1^p \cdot q_2 \cdot v_2 \cdot F_2^p + \dots + q_z \cdot v_z \cdot F_z^p}{q_1 \cdot v_1 + q_2 \cdot v_2 + \dots + q_z \cdot v_z}}$$

<b>P</b>	<b>N</b>	Dynamic equivalent load
<b>p</b>	-	Rating life exponent:

For flat cage guidance systems with rollers: p=10/3  
 For flat cage guidance systems with balls: p=3

<b>q<sub>i</sub></b>	<b>%</b>	Proportion of total duration
<b>F<sub>i</sub></b>	<b>N</b>	Variable load
<b>v<sub>i</sub></b>	<b>m/min</b>	Variable speed
<b><math>\bar{v}</math></b>	<b>m/min</b>	Dynamic equivalent speed

Operating life

The operating life is the actual expected rating life of a flat cage guidance system. It may differ from the nominal rating life.

Potential causes include wear and tear and/or fatigue due to:

- Soiling
- Insufficient lubrication
- Misalignment
- Movements with minimal strokes
- Vibrations during dead time (false brinelling).

The operating life of a flat cage guidance system cannot be calculated precisely in advance due to the wide range of installation and operating conditions. The most reliable information is obtained from comparisons with similar installations.

1.3.5.5 EFFECTIVE LOAD RATING

The basic dynamic and static load ratings  $C$  and  $C_0$  given for the different products relate to a cage with a theoretical length of 100 mm. This allows direct comparisons to be made between the load carrying capacities of flat cages of different series and dimensions. The effective dynamic and static load ratings  $C_w$  and  $C_{0w}$  are calculated according to the following equations for the effective cage lengths.

For needle roller flat cage assemblies:

$$C_w = C \cdot \left( \frac{L_K - 2L1 + LA}{100} \right)^{\frac{3}{4}} \cdot \left( \frac{L_K - 2L1}{100 - LA} \right)^{\frac{1}{36}}$$

$$C_{0w} = C_0 \cdot \left( \frac{L_K - 2L1 + LA}{100} \right)$$

For ball flat cage assemblies:

$$C_w = C \cdot \left( \frac{L_K - 2L1 + LA}{100} \right)^{\frac{2}{3}} \cdot \left( \frac{L_K - 2L1}{100 - LA} \right)^{\frac{1}{36}}$$

$$C_{0w} = C_0 \cdot \left( \frac{L_K - 2L1 + LA}{100} \right)$$

<b>C</b>	<b>N</b>	Basic dynamic load rating for a cage length of 100 mm (table dimensions)
<b>C<sub>0</sub></b>	<b>N</b>	Basic static load rating for a cage length of 100 mm (table dimensions)
<b>C<sub>w</sub></b>	<b>N</b>	Effective dynamic load rating
<b>C<sub>0w</sub></b>	<b>N</b>	Effective static load rating
<b>L<sub>K</sub></b>	<b>mm</b>	Cage length (figure 9)
<b>L1</b>	<b>mm</b>	Distance between the first and last pocket centre and the end of the cage (figure 9)
<b>LA</b>	<b>mm</b>	Spacing distance in the flat cage (figure 9, table dimensions)

The values for  $C_{0w}$  and  $C_w$  correspond to the load rating calculation according to ISO 14728

△ The equations only provide precise results when the cage length  $L_K$  is based on a whole number of rolling elements per row.

Equation for verification of  $Z$ :

$$Z = \frac{L_K - 2L1}{LA} + 1 = \text{whole number}$$

$Z$  - number of rolling elements per row (figure 9)

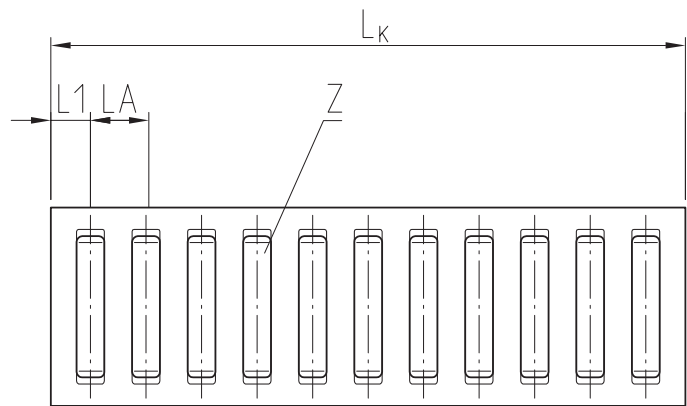


Figure 9. Dimensions to determine the effective load rating

1.3.5.6 CORRECTION FACTORS FOR LOAD CARRYING CAPACITY

The basic load ratings given for the different products only apply subject to the following requirements:

- Raceway hardness  $\geq$  HRC 58 (670HV)
- Centric load direction

Deviating conditions are to be taken into account using the following correction factors:

- Hardness factors  $f_{H0}$  or  $f_H$

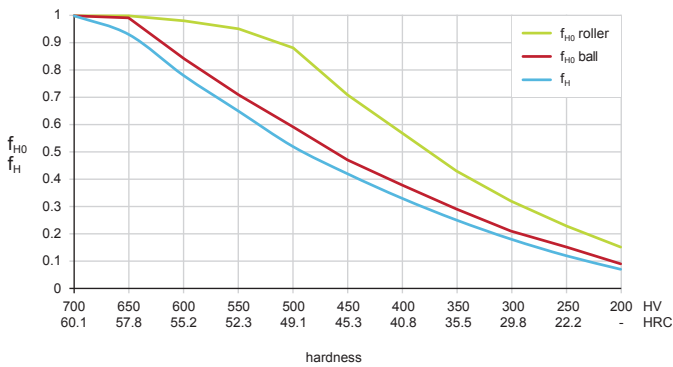


Figure 10. Hardness factors

- Load direction factor  $f_\alpha$  or  $f_{\alpha0}$

The basic load ratings for the different products only apply provided that the load operates in symmetry with the cage shanks ( $\alpha = 0^\circ$ ). The correction factor for other load directions can be obtained from the figure:

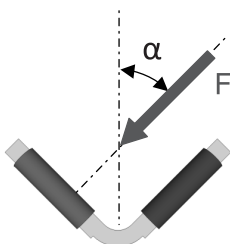
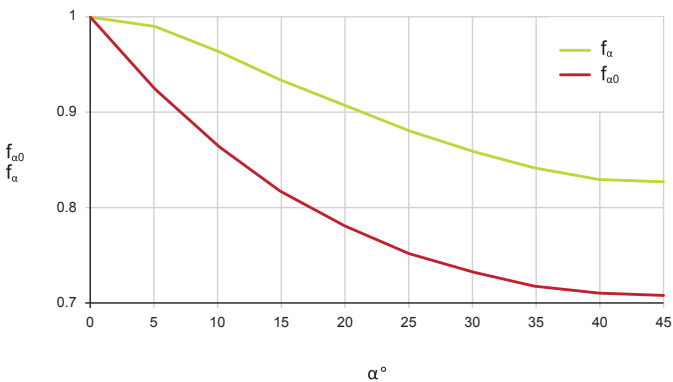


Figure 11. Load direction factor

Static load rating

$$C_{0we} = f_{\alpha0} \cdot f_{H0} \cdot C_{0w}$$

$C_{0we}$	N	Corrected effective static load rating
$f_{\alpha0}$	-	Static load direction factor
$f_{H0}$	-	Static hardness factor
$C_{0w}$	N	Static load rating for the effective cage length

Dynamic load rating

$$C_{we} = f_\alpha \cdot f_H \cdot C_w$$

$C_{we}$	N	Corrected effective dynamic load rating
$f_\alpha$	-	Dynamic load direction factor
$f_H$	-	Dynamic hardness factor
$C_w$	N	Dynamic load rating for the effective cage length

### 1.3.5.7 ECCENTRIC LOAD

In a linear guidance system without recirculating rolling elements, the flat cage always travels half the stroke of the mobile guideway and thus alters its position in relation to the load. It therefore does not generally carry an equal load. However, the load ratings given for the different products only apply with an equal load distribution.

#### Eccentric load with open layout

Open layout: see application features (page 14, figure 2)  
 In the case of an eccentric load, the load carrying capacity can be determined with the static equivalent cage load (figure 12).

$$P_0 = k_{0F} \cdot F$$

<b>P<sub>0</sub></b>	<b>N</b>	Static equivalent load
<b>k<sub>0F</sub></b>	-	Static load factor
<b>F</b>	<b>N</b>	Guide loading

#### Eccentric load with closed layout

Closed layout: see application features, (page 14, figure 1)

Linear guidance systems with a closed layout can carry additional loads and tilting moments. In these cases, the calculation of the equivalent cage load is fairly complex. EGIS offers support with corresponding calculation programmes on request (pages 26 to 31).

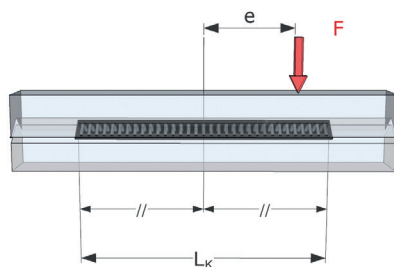
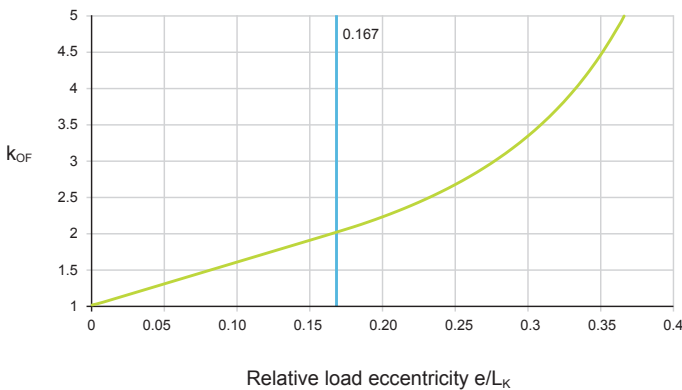


Figure 12. Static load factor for eccentrically loaded flat cages and open layout

△ If a load eccentricity of  $> 0.167$  is exceeded, only part of the rolling element is loaded. This is extremely detrimental to the load carrying capacity and rigidity of the guidance system.

## 1.3.5.8 CALCULATION

## Example

## Input data

Guideways	M 5025 and V 5025
Flat cage assembly	E-HW15
Basic dynamic load rating for a cage length of 100 mm	$C = 25960 \text{ N}$
Basic static load rating for a cage length of 100 mm	$C_0 = 88900 \text{ N}$
Operating load, functioning centrally on the guidance system (factors $f_\alpha, f_{\alpha 0}, k_{0F} = 1$ )	$F = 9500 \text{ N}$
Dynamic equivalent load	$P = 9500 \text{ N}$
Static equivalent load	$P_0 = 9500 \text{ N}$
Distance from extreme stroke positions	$H = 100 \text{ mm}$
Number of double strokes per minute	$n_{osz} = 50 \text{ min}^{-1}$
Cage length	$L_K = 300 \text{ mm}$

## Required data

Static load safety factor	$S_0$
Nominal rating life	L and $L_h$

## Calculation

Verification of number of rolling elements per row (LA, L1, dimension tables)

$$Z = \left( \frac{L_K - 2L1}{LA} \right) + 1 \quad Z = \left( \frac{300 - 7}{4.5} \right) + 1 = 66$$

For calculation:

$$L_K = (Z - 1) \cdot LA + 2L1 = 299.5 \text{ mm}$$

Effective static load rating

$$C_{0w} = C_0 \cdot \frac{L_K - 2L1 + LA}{100}$$

$$C_{0w} = 88900 \cdot \frac{297}{100} = 264000 \text{ N}$$

Static load safety factor  $S_0$

$$S_0 = \frac{C_{0w}}{P_0} \quad S_0 = \frac{264000}{9500} = 27.8$$

Effective dynamic load rating  $C_w$ :

$$C_w = C \cdot \left( \frac{L_K - 2L1 + LA}{100} \right)^{3/4} \cdot \left( \frac{L_K - 2L1}{100 - LA} \right)^{1/36}$$

$$C_w = 25960 \cdot \left( \frac{295}{100} \right)^{3/4} \cdot \left( \frac{288}{95.5} \right)^{1/36} = 60250 \text{ N}$$

Nominal rating life L:

$$L = \left( \frac{C_w}{P} \right)^{10/3} \quad L = \left( \frac{60250}{9500} \right)^{10/3} = 472 \cdot 10^5$$

Nominal rating life  $L_h$

$$L_h = \frac{8.33 \cdot 10^5}{H \cdot n_{osz}} \cdot \left( \frac{C_w}{P} \right)^{10/3}$$

$$L_h = \frac{8.33 \cdot 10^5}{100 \cdot 50} \cdot 472 = 78600 \text{ h}$$

## Calculation programme

The calculation on pages 19 to 25 can be used to establish an initial layout for flat cage guidance systems. The equations are based on a defined static system. In practice, however, an undefined static system is generally used. This does not allow for simple calculations; in order to obtain a precise calculation, the preload and internal load distribution have to be taken into account. The load carrying capacity and rigidity for different loads can be calculated using a corresponding Excel help file egis.

Our Excel help file egis determines the following data:

- Static load safety factor
- Displacement stemming from the elasticity of the bearing.

The non-linear deflection of the rolling elements is taken into account in this context.

The connecting structure is assumed to be rigid.

The following details are required for the calculation of every load scenario (figure 14 and datasheet, page 27):

- Size and position of the elements of the guidance system
- Position of the drive axis
- Position of the loading point and external load components
- Shear-free moments
- Position of the balance points and size of weights
- Kinetic valves
- Duration of particular steps

The geometry and loads can be described simply using the following datasheet.

A right-handed coordinate system is used for the description. The right-hand rule applies for moments.

Position of co-ordinate origin:

- Carriages in central stroke position
- x: centre of bearing cage length
- y: centre plane of guideways
- z: central between the guideways

One or more stroke positions deviating from the central position may be used for the calculation.

The data entered in the datasheet correspond to the guidance system presented in figure 15 as an example.

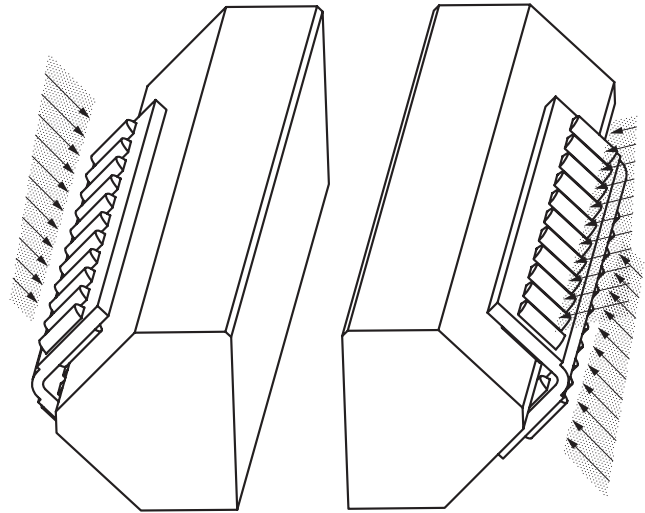


Figure 13. Internal load distribution in the case of loads produced by loads and moments

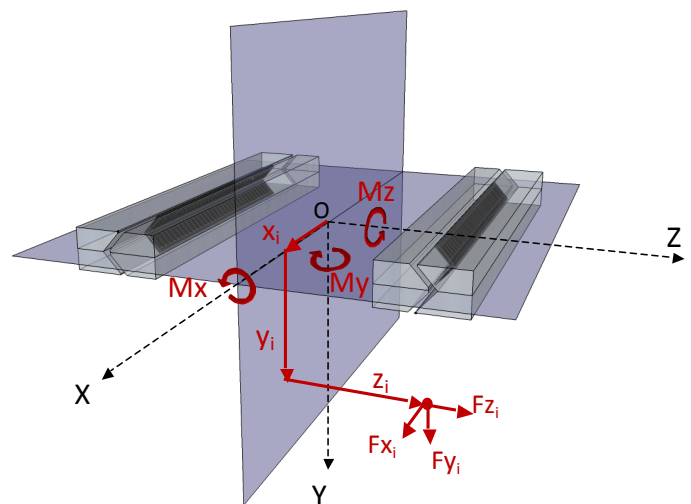


Figure 14. Coordinate system



Example: horizontal drilling carriage

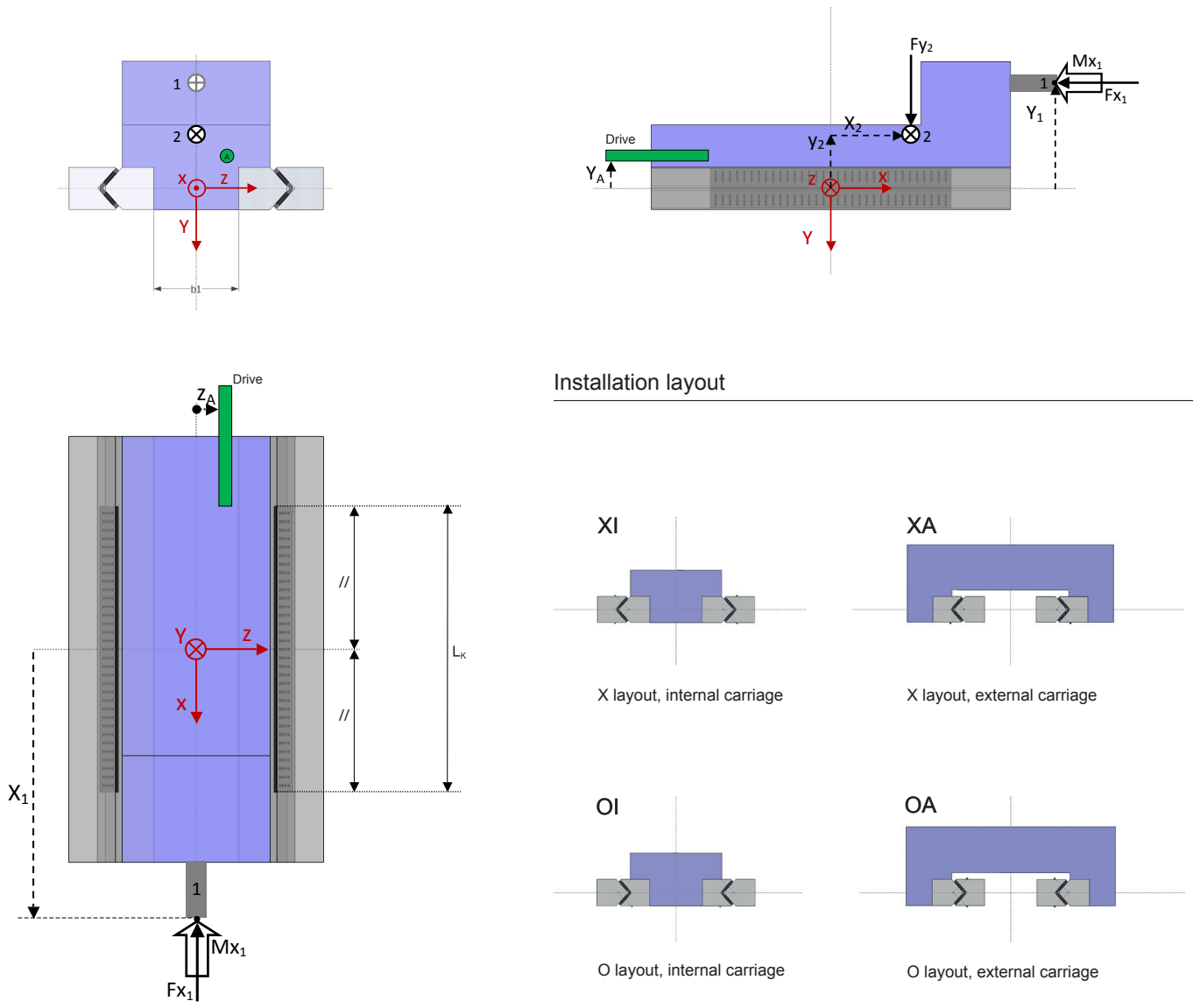


Figure 15. Geometry and load details

Example: horizontal drilling carriage

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## Results

Power on carriage drive  
 Resulting load on guidance system:

**F<sub>x</sub>** = -1200 N  
**F<sub>y</sub>** = 800 N  
**F<sub>z</sub>** = 0 N  
**M<sub>x</sub>** = -20000 Nmm  
**M<sub>y</sub>** = -36000 Nmm  
**M<sub>z</sub>** = -82400 Nmm

Required preload power **P<sub>v</sub>** = 3050 N

Percentage rate of static load carrying capacity **C<sub>0</sub>**: 2.54 %

Displacement of the guidance system:

**del y** = 0.13992 μm  
**del z** = -0.00719 μm  
**phi x** = -0.00152 mrad  
**phi y** = -0.00389 mrad  
**phi z** = -0.00863 mrad

Static load safety factor: **S<sub>0</sub>** = 31.6

Displacement at point i (μm)

Nr.	del ix	del iy	del iz
1	-0.27622	0.18561	0.04155
2	-0.77686	-1.54327	0.88915
3	-0.34527	-0.33483	0.26788

The calculated displacements only include the effect of the deflection of rolling elements and raceways. The deformation of the connecting structure is not taken into account.

### 1.4 RIGIDITY

Flat cage guidance systems use needle rollers, cylindrical rollers or balls as load-bearing rolling elements. Needle rollers and cylindrical rollers possess a line contact in the rolling contact whilst balls possess a point contact. The operating load  $F$  creates an elastic deformation at the contact points and therefore causes the raceways to converge around the deflection  $\delta$ .

Guidance systems with needle rollers are significantly more rigid than those with cylindrical rollers given the same space requirement due to the large number of contact lines. The rigidity of guidance systems with balls is considerably lower on account of the point contact (figure 16).

Rigidity is the relationship between the load and deformation:

$$C_L = \frac{F}{\delta}$$

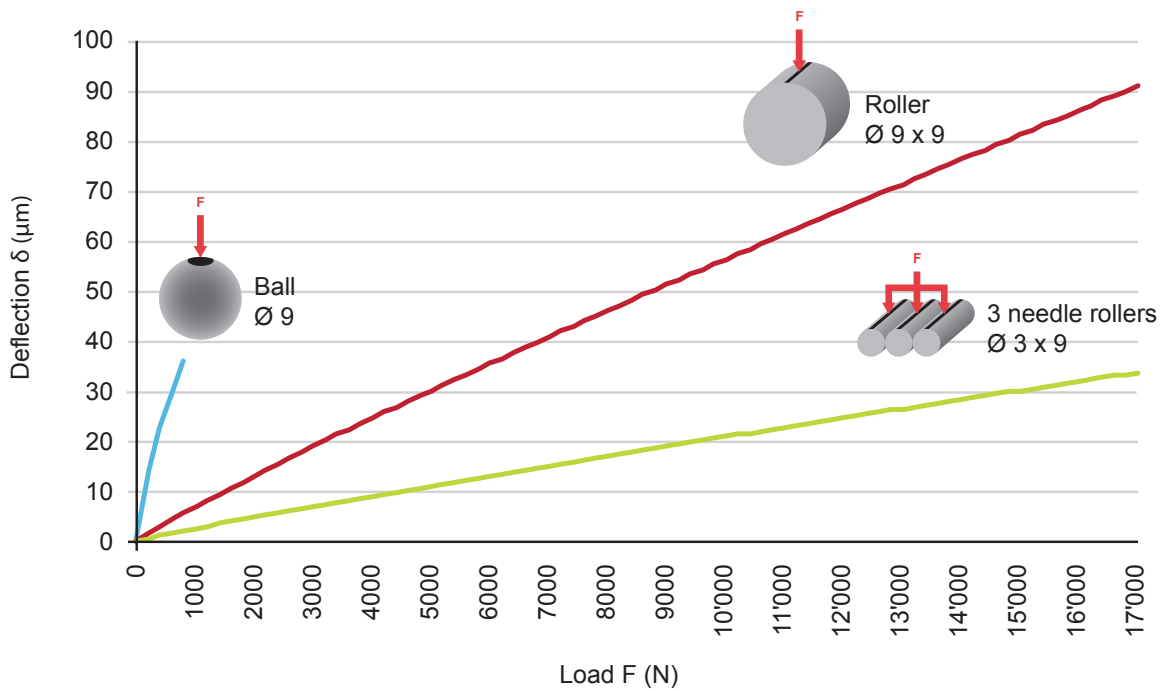


Figure 16. Comparison between rolling element types with the same space requirement

△ Deformations of the connecting structure, settlement phenomena, etc. are not taken into account. Deformation can therefore be more significant in practice.

In guidance systems with M and V guideways in a closed layout, the rigidity can be increased by pre-loading (preloading, page 32).

The rigidity is dependent on the load and the number and geometry of the rolling elements.

Flat cage guidance systems with line contact

$$\delta = K \cdot (F/Z)^{0.9} / L_w^{0.8}$$

$$C_L = 1/K \cdot F^{0.1} \cdot Z^{0.9} \cdot L_w^{0.8}$$

Flat cage guidance systems with point contact

$$\delta = K \cdot (F/Z)^{2/3} / D_w^{1/3}$$

$$C_L = 1/K \cdot F^{1/3} \cdot Z^{2/3} \cdot D_w^{1/3}$$

<b>δ</b>	<b>μm</b>	Elastic deformation at the contact points, convergence of the two raceway levels
<b>K</b>	-	Factor for the determination of elastic deformation dependent of the type (table 17)
<b>F</b>	<b>N</b>	Operating load
<b>Z</b>	-	Number of rolling elements per row
<b>L<sub>w</sub></b>	<b>mm</b>	Rolling element length
<b>C<sub>L</sub></b>	<b>N/μm</b>	Rigidity of the flat cage guidance system
<b>D<sub>w</sub></b>	<b>mm</b>	Ball diameter.

Calculation example

Guideway	M 5025 and V 5025
Flat cage assembly	E-HW15 x 300
Operating load	F = 9500 N
Number of rolling elements per row	Z = 66
Rolling element length	L <sub>w</sub> = 6.8 mm
Type factor (table)	K = 0.0822

Elastic deformation calculation:

$$\delta = K \cdot (F/Z)^{0.9} / L_w^{0.8}$$

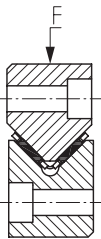
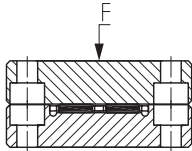
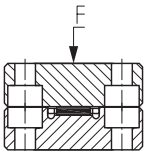
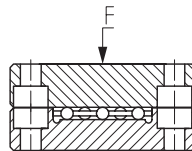
$$\delta = 0.0822 \cdot (9500/66)^{0.9} / 6.8^{0.8} = 1.6 \mu\text{m}$$

Rigidity calculation:

$$C_L = 1/K \cdot F^{0.1} \cdot Z^{0.9} \cdot L_w^{0.8}$$

$$C_L = 1/0.0822 \cdot 9500^{0.1} \cdot 66^{0.9} \cdot 6.8^{0.8} = 6100 \text{ N/}\mu\text{m}$$

Table 17: factor K for the determination of elastic deformation

Guideway Type	Factor K	Guideway Type	Factor K
	0.0822		0.0426
	0.0794		0.8776

## 1.5 PRELOAD

The preload of flat cage guidance systems can be useful for the following reasons:

- Increase of rigidity
- Improvement of running accuracy
- Improvement of load distribution and reduction of maximum load on the outer rolling elements
- Increase of permissible moments

The preload influences the displacement resistance and rating life.

Reference value for the preload: 2 to 3% of  $C_0$ .  
The optimum preload for concrete load datas can be determined using our Excel help file egis.

An optimum preload reduces the possibility of uncontrolled movement in the flat cage assembly (cage roaming).

In order to guarantee that the rigidity of our linear guidance systems is fully optimised, care must be taken to ensure that the connecting structure is sufficiently rigid and precise.

In the case of imprecise connecting structures or ones which can be easily deformed, angle errors may occur between the raceways which create an increased load at the ends of the rolling elements.

This would not result in increased rigidity but rather the end load would reduce the operating life.

### 1.5.1 SETTING THE PRELOAD

The preload can be measured and set using different methods:

- using pressure screws with a setting torque according to the table on page 33
- by means of FRV carriage displacement resistance (see below)
- by measuring the deformation of the connecting structure.

$$F_{RV} = \frac{C_{0w}}{40'000}$$

$F_{RV}$	<b>N</b>	Carriage displacement resistance
$C_{0w}$	<b>N</b>	Effective static load rating

Requirements:

- Preload 2,5%  $C_0$
- Lubricated guidance system without operating load
- Movement at approx. 0,05 m/s

1.5.1.1 PRELOAD SCREWS

In the case of small loads ( $S_0 > 5$ ) the guidance system can be preloaded by means of preload screws. A smaller effective span can be obtained by inserting the preload screws (stud screws according to ISO 4026, DIN 913) between the attachment screws and at the end of the guideway (table 18, figure 19).

1.5.1.2 GUIDEWAYS WITH ADJUSTING GIB

The use of ML guideways with an adjusting gib is recommended where a high degree of rigidity is required or with larger loads ( $S_0 < 5$ ). This ensures that the preload is distributed evenly over the entire guideway length.

TABLE 18. PRELOAD SCREWS / SETTING TORQUE

Guideways	Flat cage assembly	Preload screw		Setting torque
		Dimension	Distance / mm	$M_E^{1)}$ / Nm
M / V 3015	E-HW10	M4	40	0.34
M / V 4020	E-HW15	M6	80	1.2
M / V 5025	E-HW16	M6	80	1.8
M / V 4525	E-HRW50	M6	80	1
M / V 6035	E-HW20	M8	100	2.9
M / V 6535	E-HRW70	M8	100	3.5
M / V 7040	E-HW25	M10	100	5.7
M / V 8050	E-HW30	M12	100	7.7

1) Torque for a preload of 2,5%  $C_0$

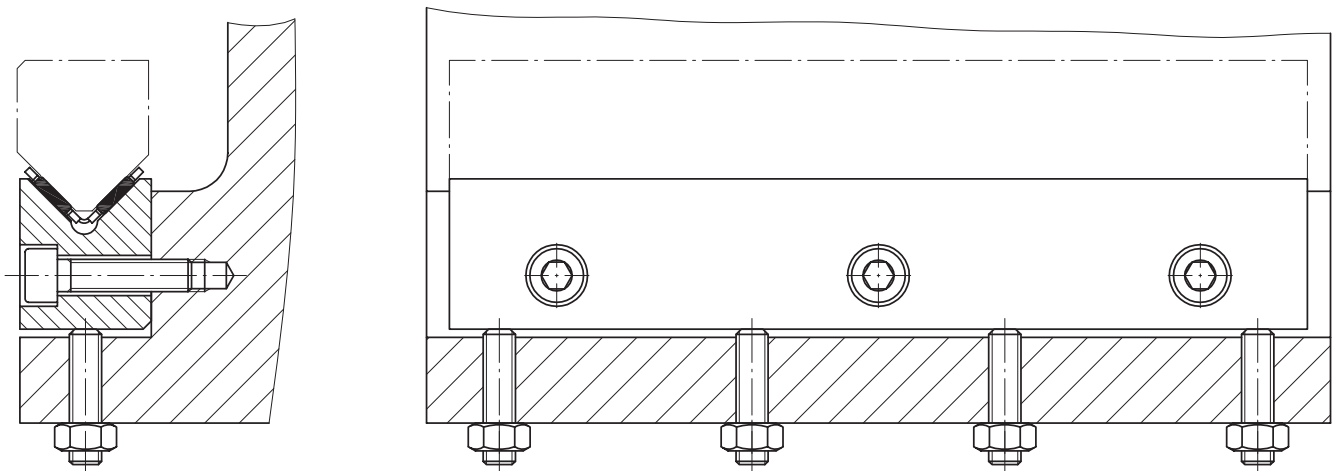


Figure 19. Position of the pressure screws

## 1.6 LUBRICATION

Machine performance is influenced considerably by the installed flat cage guidance systems. Lubrication plays an important role in this context.

The lubricant minimises friction and wear in the rolling contact and at the bearing points between the cage and the rolling elements. Lubricants also protect against corrosion and offer a support to the seal.

### 1.6.1 LUBRICANTS

Grease or oil can be used as lubricants. The choice of lubrication procedure is made on the basis of technical and economic considerations:

Advantages of lubrication with grease:

- long relubrication intervals
- reduced structural expenditure when relubrication is not required
- thickener in the grease creates emergency operation features
- support to the seal

Advantages of lubrication with oil:

- excellent lubrication application
- dirt is flushed out
- heat is dissipated

Flat cage guidance systems only require minimal lubrication. They are supplied with a preservative. The preservative is compatible with grease and oils.

Flat cage guidance systems are generally operated in areas of mixed friction. For this reason, doped lubricants with high-pressure additives should be used (code letter P according to DIN 51502).

△ Cooling lubricants must not be used as they thin out the lubricants and can cause corrosion. Lubricants with solid additives must not be used.

### 1.6.2 LUBRICATING WITH GREASE

General recommendation:

Lithium-soap, EP-doped grease with mineral oil base.  
Specification according to DIN 51825: KP2N-20  
Base oil viscosity: ISO-VG 150 to ISP-VG220.

△  $S_0 < 8$  essential with large loads  
EP-doped greases with base oil viscosity of ISO-VG 220 should be used.

### 1.6.2.1 PRIMARY OPERATION AND GREASE QUANTITY

The guidance system must be protected against soiling before and during assembly.

Without relubrication equipment:

For the first lubrication application, spread the grease quantity according to the table over both sides in the cage pockets and thinly lubricate the guideway raceways.

With relubrication equipment:

First fill the feed line with grease and thinly lubricate the raceways. Then assemble the guidance system and feed in the grease according to the table. Move the guide system several times during this procedure over the entire stroke to ensure that the grease is evenly distributed.

TABLE 20. GREASE QUANTITIES FOR PRIMARY LUBRICATION (GUIDELINES)

Flat cage/Series	Grease quantity for primary lubrication g/100 mm cage length <sup>1)</sup>
E-HW 10	0.6
E-HW 15 <sup>2)</sup> / E-FFW 2025 / E-FF 2025 ZW	0.6
E-HW 20 <sup>2)</sup> / E-FFW 2535 / E-FF 2535ZW	1
E-HW 25 <sup>2)</sup> / E-FFW 3045 / E-FF 3045 ZW	1.3
E-HW 30 <sup>2)</sup> / E-FFW 3555 / E-FF 3555 ZW	2.1
E-HRW 50	1.5
E-HRW 70	3.5
E-HRW 100	6.6
E-H 10 <sup>2)</sup> / E-FF 2010	0.3
E-H 15 <sup>2)</sup> / E-FF 2515	0.5
E-H 20 <sup>2)</sup> / E-FF 3020	0.7
E-H 25 <sup>2)</sup> / E-FF 3525	1.1

1) In case of high speeds only about 25% of the quantity

2) With flat cage assemblies with damping about 80% of the quantity

### 1.6.2.2 RELUBRICATION

Relubrication should be carried out at least once a year with approximately 50% of the grease quantity used for the primary lubrication. More frequent relubrication with partial quantities is recommended. The optimum time and quantities can only be determined under operating conditions and with an adequate observation period.

### 1.6.3 LUBRICATING WITH OIL

General recommendation:

CLP lubricating oils according to DIN 51517 and  
HLP according to DIN 51524

Operating temperatures from 0 °C to +70 °C:  
Viscosity between ISO-VG 32 and ISO-VG 68

Low temperature range:  
Viscosity ISO-VG 10 to ISO-VG 22

CGLP raceway oils can be used up to ISO-VG 220

Oil is fed in by oil impulse or drop feed. Pneumatic oil lubrication is recommended for working conditions with a significant risk of soiling. The slight excess pressure occurring in the guidance system enhances the effectiveness of the existing seals.

It is important to observe the layout (figure 21) when feeding in the lubricating oil so that the lubricant can reach all the rolling element rows.

If the oil manufacturer has not provided any details or experiences, the behaviour of the lubricating oil must be verified under operating conditions in comparison with the materials used in the guidance system.

Mineral oils can generally be mixed together.

However, synthetic oils must be verified in relation to miscibility and compatibility.

In case of doubt, contact the lubricant supplier.

#### Primary operation

Oil the guidance system and protect it against soiling during assembly.

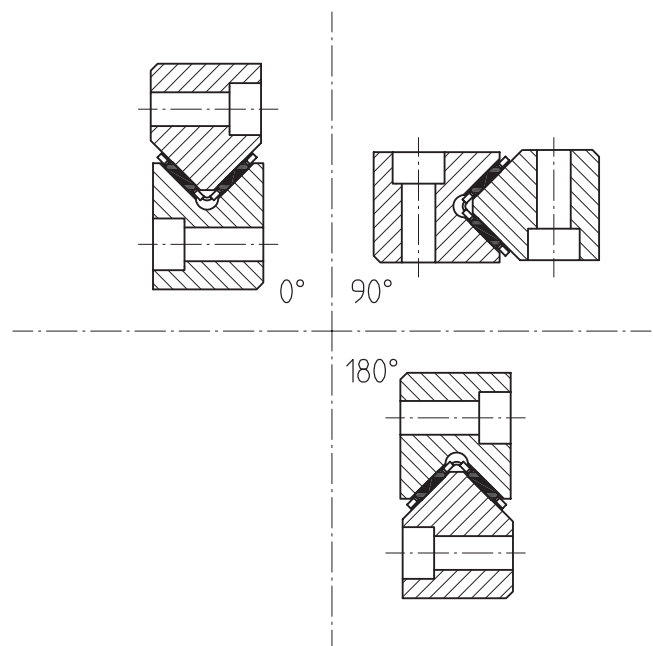


Figure 21. Layouts

### 1.7 FRICTION

As is the case of all roller bearings, flat cage guidance systems have virtually low friction during the start-up process and in motion. This means that no “stick-slip effect” is produced compared with sliding friction.

Friction (displacement resistance FR) is made up of the following components with different dependencies:

$$F_R = F_{R1} + F_{R0} + F_{RA}$$

Friction component		Dependency
Rolling friction	$F_{R1}$	Load/lubrication condition
Lubricant friction	$F_{R0}$	Cage dimensions Stroke speed Lubricant
Wiper friction	$F_{RA}$	Configuration, preload

Primary lubrication or relubrication produce temporarily raised lubrication friction.

Wiper friction  $F_{RA}$

The wiper friction arises from the length of the wiper lip and the lip preload. This can be influenced considerably by the wiper assembly.

Reference value per wiper:

Profile shape M/V  $F_{RA} = 0.20 \cdot B$

Profile shape J/S  $F_{RA} = 0.15 \cdot B$

$F_{RA}$	<b>N</b>	Friction per wiper Guideway width
<b>B</b>	<b>mm</b>	

Load-dependent rolling friction  $F_{R1}$

$$F_{R1} = \mu \cdot F$$

$F_{R1}$	<b>N</b>	Load-dependent friction component
<b>F</b>	<b>N</b>	Flat cage load
$\mu$	-	Friction coefficient

With lubrication, the friction coefficient amounts to  
0.00035 for flat cage assemblies  
0.00050 for angled flat cage assemblies

Lubricant friction  $F_{R0}$

$$F_{R0} = f_0 \cdot (v \cdot v)^{2/3} \cdot B1 \cdot L_k^{1/3} \cdot 10^{-6}$$

$F_{R0}$	<b>N</b>	Lubricant friction component in displacement friction
$f_0$	-	Type factor $f_0 = 85$ for flat cage assemblies $f_0 = 120$ for angled flat cage assemblies
$v$	<b>mm<sup>2</sup>s<sup>-1</sup></b>	Lubricant viscosity at operating temperature Viscosity of base oil with grease lubrication
$v$	<b>m/min</b>	Speed
<b>B1</b>	<b>mm</b>	Cage width
<b>L<sub>k</sub></b>	<b>mm</b>	Bearing cage length

## 1.8 PROTECTION AGAINST SOILING

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In order to ensure that flat cage guidance systems operate safely it is extremely important to protect them against soiling.

In many cases, wipers will suffice to keep the raceways clean. They must be positioned on the raceways throughout the entire movement.

Complete solutions for M and V guideways with standard wipers and integrated longitudinal seals (suffix ..ZZ, ..PP) or seals in the connecting structure may be used for more demanding cases.

## 1.9 OPERATING LIMITS

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### 1.9.1 Operating temperatures

Linear guidance systems with metallic flat cages are suitable for continuous temperatures of up to +150 °C.

Suitable lubricants must be used in this case. The guideways must be heat-stabilised at higher operating temperatures (further information can be obtained from EGIS).

Linear guidance systems with flat cages made from plastic are suitable for temperatures of up to +120°C.

An operating temperature of +100 °C must not be exceeded when using wipers.

### 1.9.2 Accelerations

If high accelerations are recorded in a linear guidance system, EGIS light metal flat cages are particularly recommended due to their reduced weight. They can be used for accelerations up to 250 m/s<sup>2</sup>.

### 1.9.3 Speeds

Under normal conditions, speeds of up to 120 m/min can be achieved. These values depend on the size of the guide, on the lubrication, on the preload, on the load, type of mounting, and the selected rail.

1.10 INSTALLATION GUIDELINES

1.10.1 PRECISION OF THE CONNECTING STRUCTURE

The precision of the locating surfaces has a decisive influence on the accuracy and smooth running of a linear guidance system.

Perpendicularity and parallelism

The right angle between the locating surfaces must be maintained precisely (permissible error  $\pm 0,3$  mrad)

$\perp$  0.003/10

Parallelism errors on the locating surfaces must not be significantly greater than the corresponding tolerances of the guideways.

Height variation

In order to ensure that the load is distributed as equally as possible over the length of the rolling element, the height variation  $\Delta h$  should not be exceeded (figures 22 and 23).

Permissible height variation for needle roller flat cage assemblies

$$\Delta h < 0,1 \cdot b$$

Permissible height variation for cylinder roller flat cage assemblies

$$\Delta h < 0,3 \cdot b$$

$\Delta h$	$\mu\text{m}$	Permissible height variation
$b$	$\text{mm}$	Distance between guidance system centres

Surface

No particular demands are placed on the surface roughness of the locating surfaces from an operational point of view. In order to maintain a high level of form precision and a suitable measurement basis, it is nevertheless recommended that the surfaces should be precision machined and the holes carefully deburred.

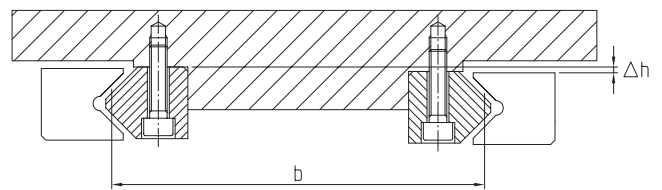


Figure 22. Height variation with a closed layout

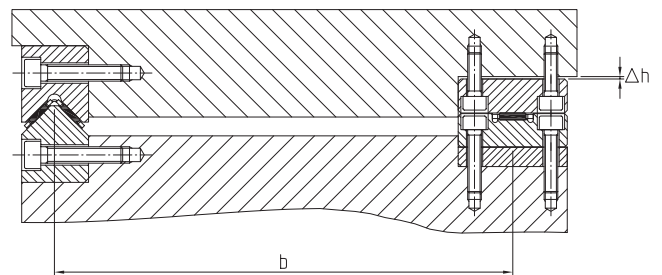


Figure 23. Equalisation of the height variation with an open layout with an insert plate

### 1.10.2 ASSEMBLY INSTRUCTIONS

#### 1.10.2.1 PRIOR TO INSTALLATION

Guideways are preserved and delivered packed in anticorrosion paper. Parts are matched by dimensions, packed in sets and numbered accordingly.

Numbering:



Unpack guideways shortly before assembly and remove the corrosion protection where applicable. Light oiling protects the guideways against corrosion during assembly. Position parts with identical set number.

Particular attention should be paid to the following points:

- Guideways with the same set number should be inserted in the same guidance system during assembly.
- Attention should be paid to the joint number at the joints.
- The M and V guideways may have different set numbers in the closed layout (figure 24).

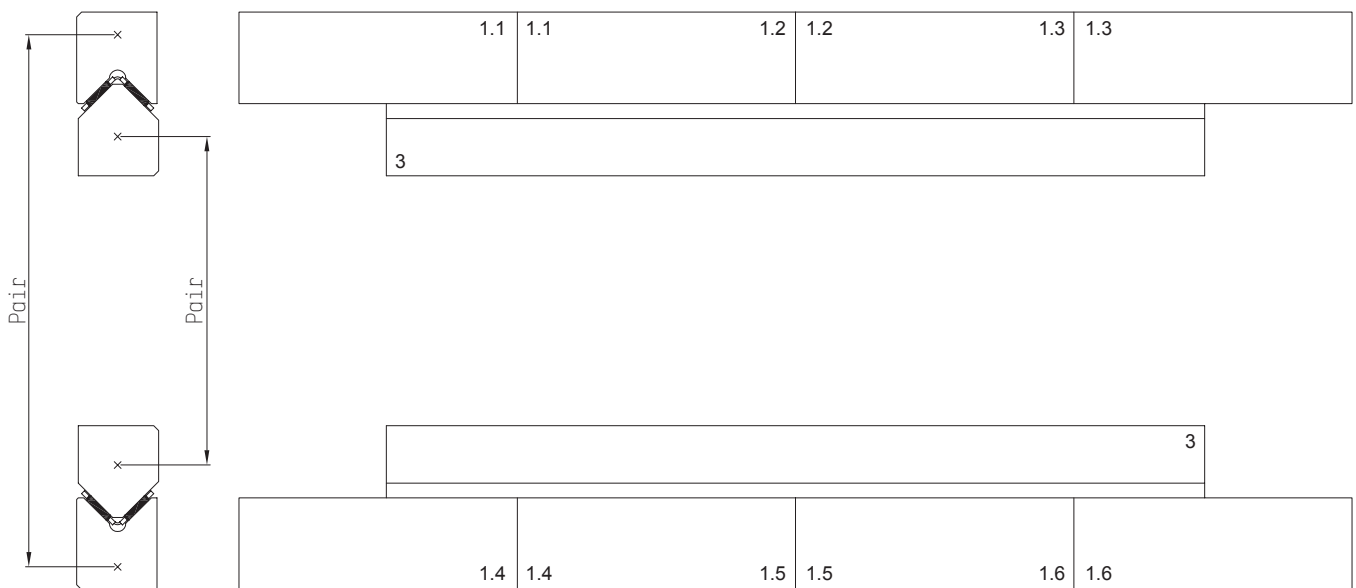


Figure 24. Numbering of single and multi-part guideways

1.10.2.2 CLOSED LAYOUT

△ Guideways which are packed in pairs must always be installed in the same guidance system.

The guideway locating faces are unlabelled and comprise significant chamfer.

Assemble the guideway pair which does not require adjustment (1) (figure 25). Clamp the guideways against the rear locating face and check for parallelism before tightening the fixing screws (figure 26).

Assemble the stationary opposing guideway (2)

Attach the adjusting guideway (3), only tightening screws slightly so that the guideway can still move.

Insert guidance system lengthways, insert cage assemblies between the guideways and position so that they do not lie against the end pieces in the final positions.

Preload adjusting guideway (3) with pressure screws (4) (figure 27) (with gib for ML guideways) (figures 29 to 31).

Initially preload around twice the required value in order to anticipate settling. Release and then set the preload to the required value. Tighten fixing screws. Screw on wipers or end pieces.

When preloading with pressure screws, adjust the latter in two steps to the required tightening torque and tighten with a counter nut or screw locking device.

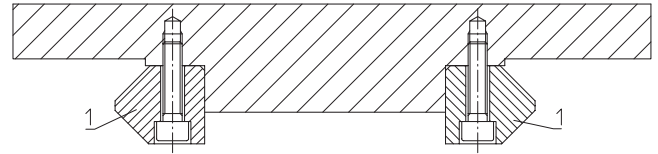


Figure 25. Assembly.

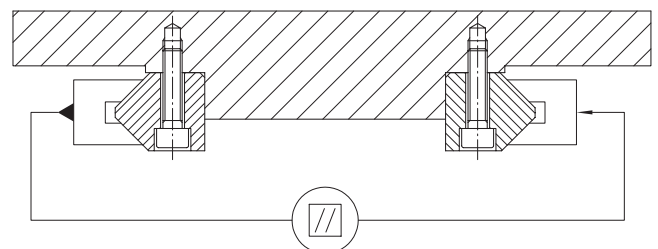


Figure 26. Parallelism verification

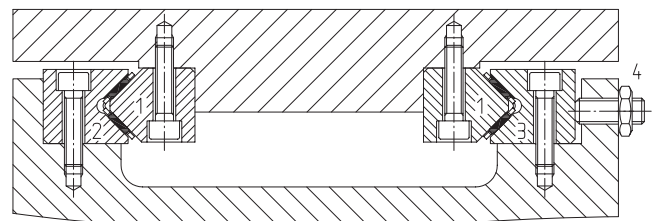


Figure 27. Preload.

△ Only tighten pressure screws which are supported by the flat cage assembly (see figure 28).

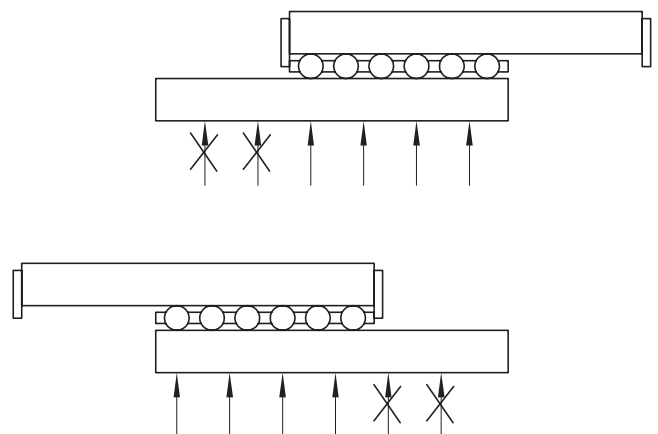


Figure 28. Preload adjustment.

If the preload force is adjusted over ML- guideways with an adjusting gib, the following procedure should be followed: push the adjusting gib under the ML guideway and adjust the guidance system free from clearance (figure 29). Shorten the unhardened gib on the adjustment side of the guideway so that it is approximately 3 mm short of the front side of the guideway (figure 29). Shorten the opposite side of the gib flush with the end of the guideway.

Preload the gib by inserting a soft bolt (figure 30). A 1 mm displacement of the gib produces a height adjustment of 15  $\mu\text{m}$ .

After setting, attach the adjusting gib to the front side of the guideway with the hexagonal socket screw (figure 31).

See chapter entitled "Setting the preload" to verify the preload

### 1.10.2.3 OPEN LAYOUT

After the precision of the locating faces has been checked, particularly the height variation (see chapter on the precision of the connecting parts), the guideways can be assembled in the required sequence.

Guideways which are labelled in sets (4SX matching) must be assembled accordingly.

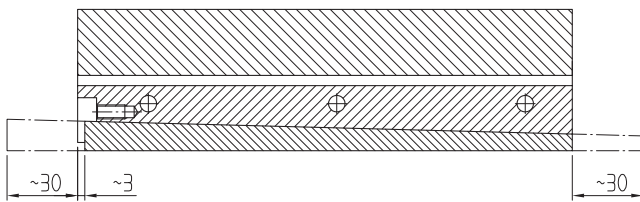


Figure 29. Inserting and shortening the adjusting gib

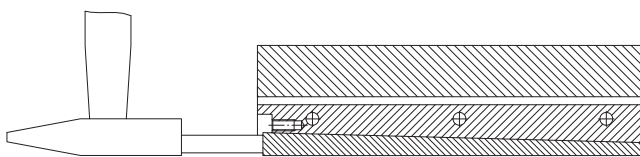


Figure 30. Setting the preload

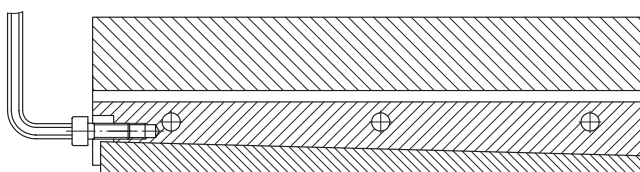


Figure 31. Attaching the adjusting gib