



# Hardened Crown Roller

## CAM Roller Technology

Roller Bearings & Linear Guideways



HARDENED CROWN ROLLER



Configure Online at  
[pbclinear.com](http://pbclinear.com)

1-800-962-8979

# Hardened Crown Rollers

## Features & Benefits

Hardened crown rollers are a superb choice for low-cost linear motion. The rollers come pre-assembled and are self-aligning for simple installation. Hardened crown rollers are great for point-to-point applications, and ensure strong, sturdy, and long-lasting linear motion.

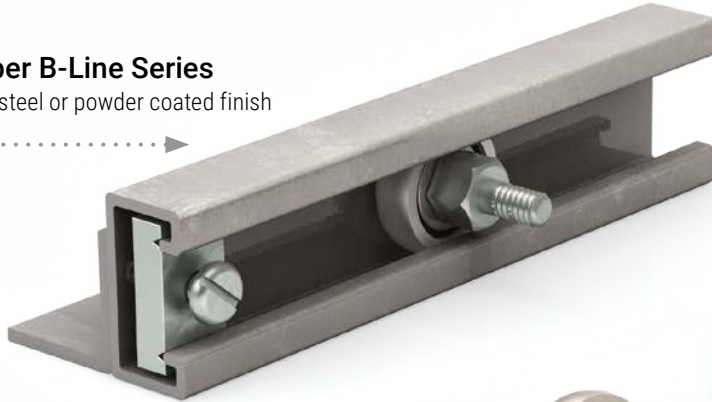
- Precision rolling element bearing with polyamide 6/6 seals riding in a Cooper B-Line Series rail
- 9/16" Hex head for easier mounting
- Available with either a 5/16-18 or M8 thread
- Maximum wheel bearing load up to 1,334 N (300 lb.)
- Maximum speed up to 762 mm/s (30 in./s)
- Rails available up to 3 m (10 ft) in steel or powder coated finish
- Contact manufacturer for longer lengths

## Accessories Available:

- Angle brackets (for welding to mounting rail)
- End stops

### Cooper B-Line Series

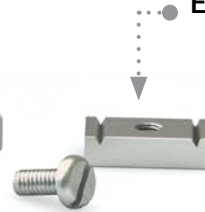
Rail in steel or powder coated finish



### Pre-Assembled Roller



### End Stops



### Angle Brackets

For welding to mounting rail



## Ordering Information

| Part No. | Description   |
|----------|---|
| PAC3016  | Hardened Crown Roller Bearing   |
| PAC3016M | Hardened Crown Roller Bearing with metric thread  |
| PAC2245  | Rail System - unpainted (specify length - priced per foot)                                    |
| PAC2247  | Rail System - black powder coat finish (specify length - price per foot)                      |
| PAC2244  | Angle Brackets - 1" Steel   |
| PAC2246  | End Stops for Rail System<br>(Included: Round head machine screw, 1/4"-20 x 3/4" Lg, slotted) |

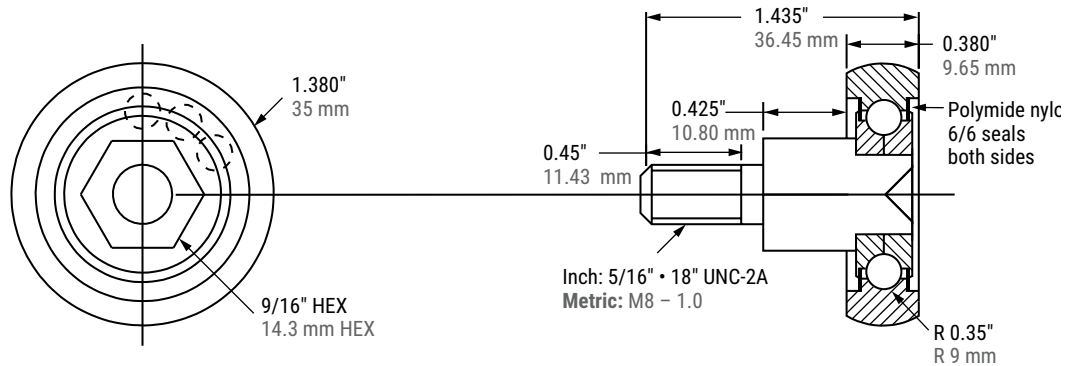
Note: PAC2247 dimensions will vary according to coating thickness.



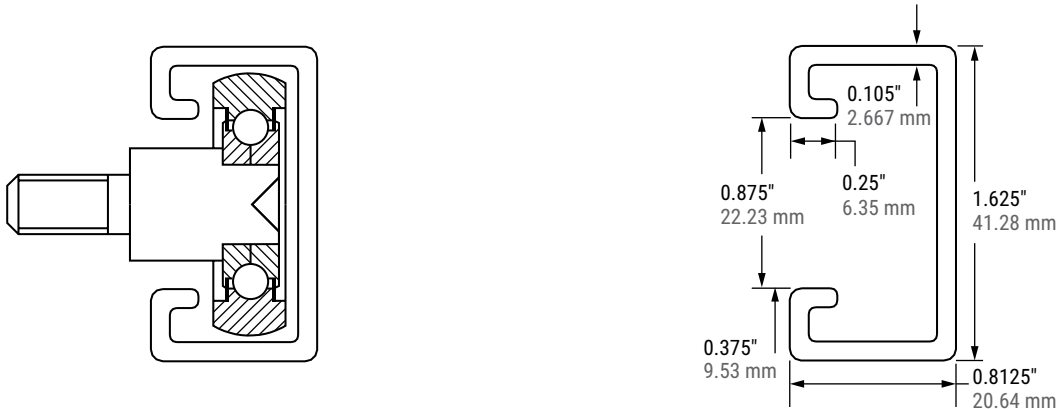
# Hardened Crown Rollers

1:1 Scale

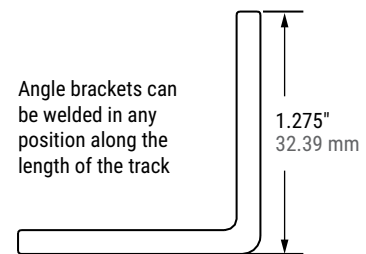
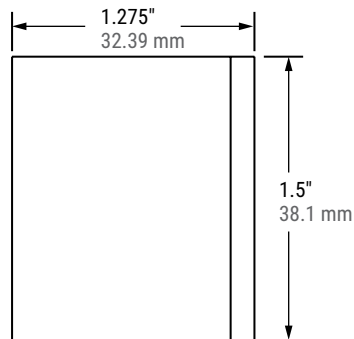
## Bearings



## Rails

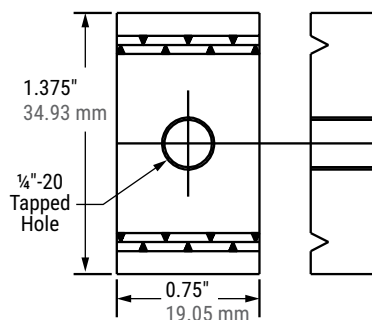


## Angle Bracket



Angle brackets can be welded in any position along the length of the track

## End Stop



Note: All metric dimensions are conversions from inch dimensions. All parts are manufactured to inch standards. See ordering information on the previous page.

# Technical • Life Calculation

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## Important Notice about Lifetime Calculations

**There is no known formula for accurately and reliably calculating the actual lifetime of a linear or rotary bearing system.**

The formulas within this section are solely based upon the statistical probability of success. It is important to recognize and distinguish between formulas of absolute certainty and probability.

Even though these formulas are not absolutely certain, they have been generally accepted as the best available method for determining bearing lifetime by the International Organization for Standardization (ISO), as well as its membership bodies; including, but not limited to: American National Standards Institute (ANSI), Deutsches Institut für Normung (DIN) & Japanese Industrial Standards Committee (JISC).

## Static & Dynamic Load Ratings

PBC Linear uses the two internationally accepted methods for calculating the Rated Lifetime, Static, and Dynamic Capacities. Per the international standard, all lifetimes are calculated to an L10 life of 100 km (105 meters or ≈3.94 million inches). The two standards used are:

- ISO76 Rolling Bearings – Static Load Ratings
- ISO281 Rolling Bearings – Dynamic Load Ratings & Rating Life

**Note:** Some suppliers may choose to rate their bearings based upon a useful life of less than 100 km or a probability of success less than 90%. This causes their bearings to falsely appear to have a higher static and dynamic load capacity. If a catalog does not specifically note L10 = 100 km, caution should be used when comparing load capacity or life values between suppliers. The most commonly used values are L10 = 50 km and L25 = 50 km. For comparison, at L10 = 100 km, an example bearing has a maximum static load of 1000 N. That exact same bearing as an L10 = 50 km maximum static load of ≈2300 N and an L25 = 50 km maximum static load of ≈4600 N!

In summary, the static load ratings are defined as the maximum applied load (or moment) which will result in the permanent deformation which does not exceed 1/10,000 of the diameter of the rolling element (ball or rod) within the bearing. The basic dynamic load rating, C, is the load of a constant magnitude and direction, which a sufficiently large number of apparently identical bearings can endure for a basic rating life of one million revolutions. It's important to note that both the static and dynamic values are determined through ISO-Approved formulas. These formulas take into account several factors, including the design, internal geometry, material type, material quality, and lubrication type.

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## Operating Lifetime

The Operating Life (or Operating Lifetime) is the actual life achieved by a rolling bearing. The actual lifetime typically varies from the calculated lifetime, sometimes significantly. It is not possible to accurately and reliably determine the actual Operating Life through calculations due to the large variety of operating and installation conditions. The most reliable method to achieve an approximation is by comparing the current application to similar applications. Primary factors which can negatively affect the life and are generally not included in calculations are:

- Contamination within the application
- Inadequate or improper lubrication
- Operational conditions different from calculated values, including unexpected forces and moments
- Insufficient and/or excessive operating clearance between the roller and guideway
- Excessive interference between roller and guideway (typically due to misalignment or excessive preload)
- Temperature out of range
- High shock loads (exceeding static load capacity)
- Vibration (which causes false brinelling resulting from fretting)
- Short stroke reciprocating motion (also causes False Brinelling)
- Damage caused during installation or from improper handling
- Improper mating surface hardness (when not used with a PBC Linear rail)

# Technical • Static Loading Calculations

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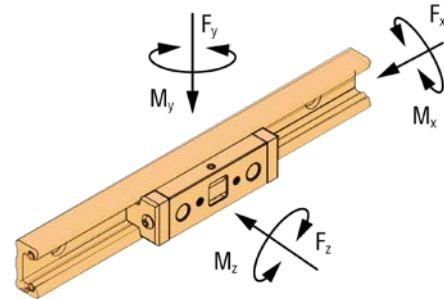
V-Guide

Hevi-Rail®

Use the values from the static load maximums given in the charts beginning on page 6 in the calculations below to verify acceptable loading conditions.

## Calculation Factors:

- $F_{za}$  and  $F_{ya}$  are the axial and radial results of external forces in newtons (N)
- $M_{xa}$ ,  $M_{ya}$ , and  $M_{za}$  are the external moments being applied in newton-meters (N-m)
- $F_y$ ,  $F_z$ ,  $M_x$ ,  $M_y$ , and  $M_z$  are the load ratings for various directions and moments
- s.f. is the relative safety factor as applied from the table below



## Single Load Force Calculations

|                                       |                                       |                                       |                                       |                                       |
|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|
| $\frac{F_{za}}{F_z} < \frac{1}{s.f.}$ | $\frac{F_{ya}}{F_y} < \frac{1}{s.f.}$ | $\frac{M_{xa}}{M_x} < \frac{1}{s.f.}$ | $\frac{M_{ya}}{M_y} < \frac{1}{s.f.}$ | $\frac{M_{za}}{M_z} < \frac{1}{s.f.}$ |
|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|

## Multiple Load Force Calculation

|   |
|---|
| $\frac{F_{za}}{F_z} + \frac{F_{ya}}{F_y} + \frac{M_{xa}}{M_x} + \frac{M_{ya}}{M_y} + \frac{M_{za}}{M_z} < \frac{1}{s.f.}$ |
|---|

## Calculation Factors

Use the following variables with the equations below to calculate the approximate travel life of Redi-Rail® carriages under various loading conditions.

- L = Estimated travel life in meters (m)
- $F_{za}$  and  $F_{ya}$  are the axial and radial results of applied external forces in newtons (N)
- $M_{xa}$ ,  $M_{ya}$ , and  $M_{za}$  are the external moments being applied in newton-meters (Nm)
- $F_d$  is the dynamic slider capacity constant from the charts beginning on page 6
- $F_y$ ,  $F_z$ ,  $M_x$ ,  $M_y$ , and  $M_z$  are the load ratings for various directions and moments as found beginning on page 6
- s.f. is the relative safety factor from the table below

Weqv is the total radial load found from the equation:

|   |
|---|
| $W_{eqv} = F_z \cdot \left( \frac{F_{za}}{F_z} + \frac{M_{xa}}{M_x} + \frac{M_{ya}}{M_y} + \frac{M_{za}}{M_z} \right) + F_{ya}$ |
|---|

Life Calculation:

|   |
|---|
| $L = \left( F_d / W_{eqv} \cdot s.f. \right)^3 \times 100,000 \text{ meters}$ |
|---|

## Safety Factor

- Use the "s.f." to adjust for dynamic forces and conditions particular to the application

| Application Condition   | S.F.  |
|---|-------|
| Consistently smooth motion with low frequency of travel reversal, slow speed (<30% MAX), no shock load or vibration, no elastic yield or deformation, clean environment | 1-1.5 |
| Normal assembly or shop floor conditions, moderate speed (30% MAX to 75% MAX), normal shock or vibration conditions   | 1.5-2 |
| Frequent reversal of travel, high speeds (>75% MAX), shock loads and/or vibration present, high elastic yield or deformation, heavy dirt and dust in environment        | 2-3.5 |

# Technical • Static Loading Calculations

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## Load Calculations

L = applied load/number of wheel pairs  
 $L_R$  = wheel radial load  
 $L_O$  = wheel load from moment  
 A = load offset dimension

B = track width dimension  
 FA = .5 for light duty, well lubricated use  
 FA = 1 for normal lubricated use  
 FA = 2 for dry, or harsh environments

## Horizontal Motion – Center Loaded

$$L_{O1} = \frac{L \cdot (B - A) \cdot FA}{B} \quad L_{O2} = (L \cdot FA) - L_{O1}$$

Compare the greater of these loads to the rated moment and radial load capacities

Example:

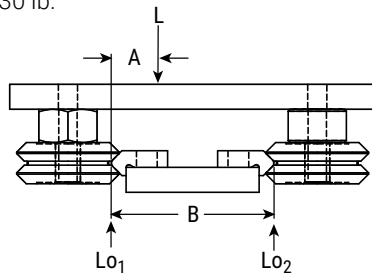
Load is 100 lb. on 4 wheel carriage:

$L = 100/2$  pair wheels = 50 lb.

$A = 4"$ ,  $B = 10"$ ,  $FA = 1$

$$L_{O1} = \frac{50 \cdot (10 - 4) \cdot 1}{10} = 30 \text{ lb.}$$

$$L_{O2} = 50 - 30 = 20 \text{ lb.}$$



## Horizontal Motion – Overhung Load

$$L_{O1} = \frac{L \cdot A \cdot FA}{B} \quad L_{O2} = (L \cdot FA) + L_{O1}$$

Compare the greater of these loads to the rated moment and radial load capacities

Example:

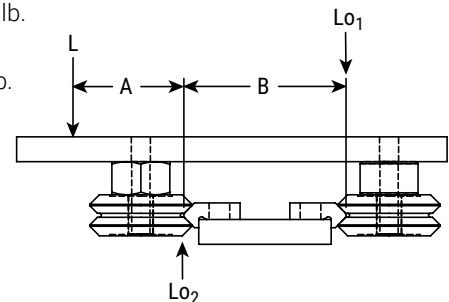
Load is 100 lb. on 4 wheel carriage:

$L = 100/2$  pair wheels = 50 lb.

$A = 4"$ ,  $B = 6"$ ,  $FA = 1$

$$L_{O1} = \frac{50 \cdot 4 \cdot 1}{6} = 33 \text{ lb.}$$

$$L_{O2} = 50 + 33 = 83 \text{ lb.}$$



## Vertical Motion

$$L_{O1} = \frac{L \cdot A \cdot FA}{B} \quad L_R = (L \cdot FA) + L_{O1} \quad L_{O1} = L_{O2}$$

Compare the greater of these loads to the rated moment and radial load capacities

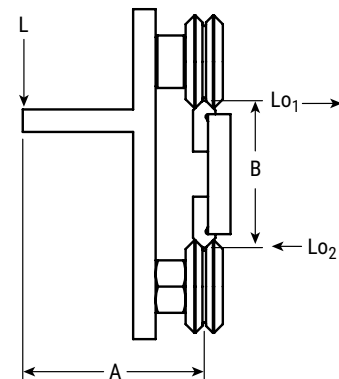
Example: Load is 100 lb. on 4 wheel carriage:

$L = 100/2$  pair wheels = 50 lb.

$A = 4"$ ,  $B = 6"$ ,  $FA = 1$

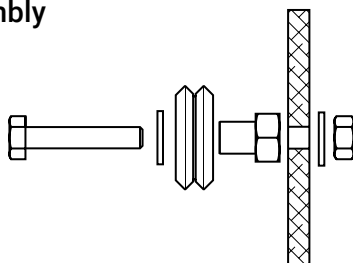
$$L_{O1} = \frac{50 \cdot 4 \cdot 1}{6} = 33 \text{ lb.}$$

$$L_R = (50 \cdot 1) + 33 = 83 \text{ lb.}$$



## Wheel/Bushing Assembly

Use SAE series N flat washers and lock washers to secure the wheel bushing assemblies



| Bushings |         |        |           |
|----------|---------|--------|-----------|
| Inch     |         | Metric |           |
| VB1      | #6      | MVB1   | M4        |
| VB2      | 1/4     | MVB2   | M6        |
| VB3      | 5/16    | MVB3   | M8        |
| VB4      | 3/8     | MVB4   | M10       |
| V-Rail   |         |        |           |
| VR1      | #6, M3  | VR3    | 1/4", M6  |
| VR2      | #10, M6 | VR4    | 5/16", M8 |

# Technical • Specifications & Cantilevered Loads

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## Technical Specifications

### Linear Bearing for Axial & Radial Loads

Prior to welding, disassemble bearing components. To avoid cracks in welded joints, please use welding electrodes and core weld for unalloyed steel.

**Outer ring** – Case-hardened steel En 31 - SAE 52100 hardened at 60+2 HRC.

**Inner ring** – Hardened steel En 31 - SAE 52100 hardened at 62-2 HRC.

**Cylindrical rollers** – Flat ground heads are hardened steel, En 31 - SAE 52100, hardened at 59-64 HRC.

**Bolt tolerance** – 0.05 mm:

**Profile rails** – High quality 18MnNb6 steel at standard lengths of 6 m (19.7 ft). Yield point of 430 N/mm<sup>2</sup>, tensile strength of 550-770 N/mm<sup>2</sup>. Rails are not hardened but have a Brinell hardness of 160-210. The guide ways in the rails should be lightly greased and not painted.

**Clamp flange** – Low carbon steel, adjustable clamp.

**Flange plate** – Low carbon steel. Special designs available, contact manufacturer.

**Seals – Fixed Axial Bearings** (HVB-053 to HVB-063): Radial roller has steel labyrinth and axial roller has rubber seals.

**Eccentric Adjustable Axial Bearings** (HVBEA-454 to HVBEA-463) Both radial roller and axial roller have rubber seals. Rubber seals are RS type.

**Lubrication** – Bearings are supplied lubricated with grease grade 3. Bearings from HVB-055 to HVB-063 can be re-lubricated with grease zerk. Adjustable bearings are not available with zerk.

**Bearing coefficient of frictions** – 0.010 static, 0.005 dynamic.

**Temperature** – Resistant from -30°C to 120°C (-22°F to 248°F).

Bearing Life Calculations:

$$L_{10} = \frac{(16,667)}{n} \cdot \left(\frac{C}{P}\right)^{10/3} \cdot (\text{Hours})$$

C = Dynamic load rating (kN)

P = Automatic dynamic load (kN)

n = Revolutions per minute (rpm)

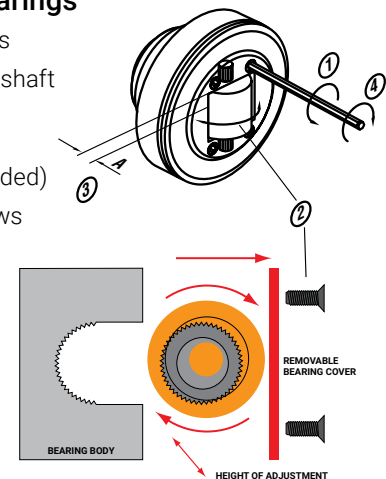
Note: Above calculation formula is for predicting life expectancy with 90% reliability level. Customers shall use their discretion to determine the reduction factor based on the actual operation needs and conditions such as reliability level, load, speed, impact, and environments.



Link to video "How to Adjust Hevi-Rail Bearing Systems"

## Adjusting Axial Bearings

1. Remove front screws
2. Rotate axial bearing shaft (see diagram below)
3. Check dimension A (repeat step 2, if needed)
4. Re-install front screws
5. Recommend use of a breakable Loctite®



## Calculation of f<sub>max</sub> for cantilevered loads

Q = Load capacity (N)

L = Load distance to suspension point (mm)

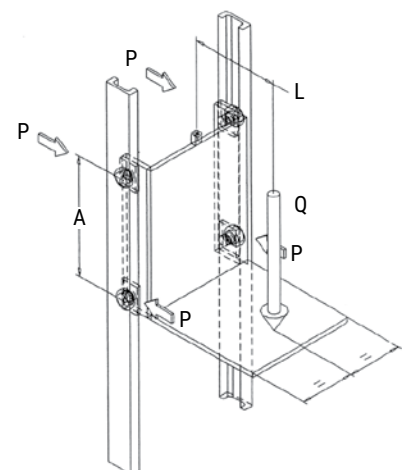
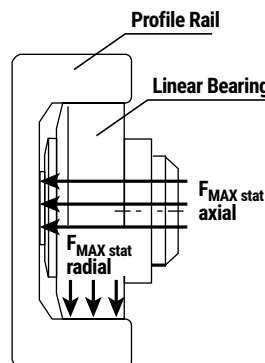
P = Suspension point

A = Bearing distance (mm)  
recommended 500 mm to 1,000 mm

$$\text{Formula: } F_{\text{MAX stat radial}} = \frac{Q \cdot L}{2 \cdot A}$$

MAX Hertzian = 850 N/mm<sup>2</sup> for all profile rails

Indicated here are F<sub>MAX stat</sub> radial + axial for each bearing



# Technical • Mounting

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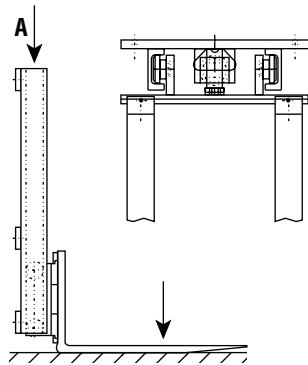
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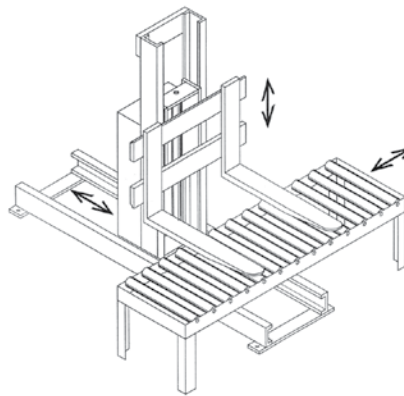
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## Mounting Configurations

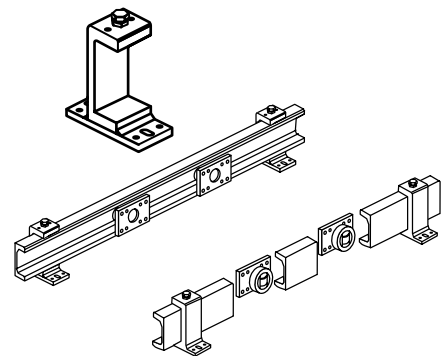
Lifting Units



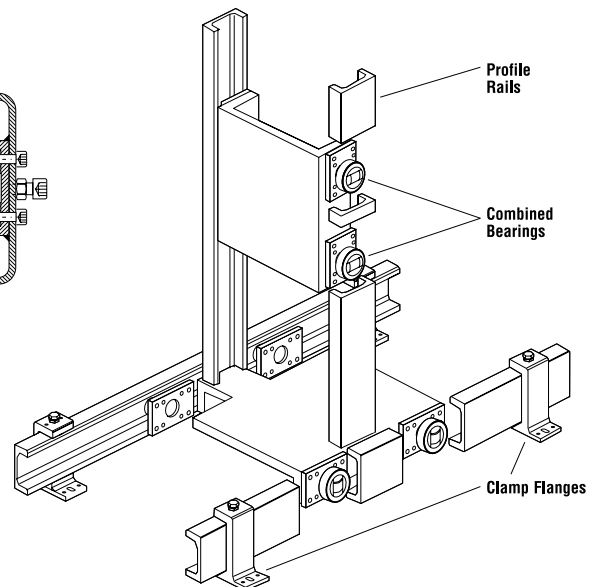
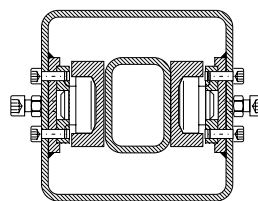
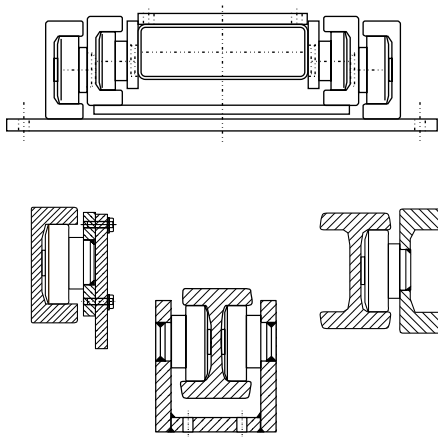
Handling Units



Adjustable Clamp System

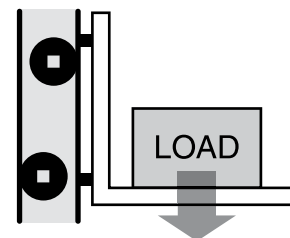
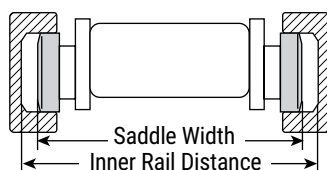


Horizontal Telescope



## Mounting Instructions

1. The overall system clearance should be 1.524 mm to 3.048 mm Inner Rail Distance = Saddle Width + (1.524 mm to 3.048 mm)
2. Verify that the axial bearing is aligned parallel to the rail; especially in vertical operations



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# Technical • Life Calculation

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In summary, the static load ratings are defined as the maximum applied load (or moment) which will result in the permanent deformation which does not exceed 1/10,000 of the diameter of the rolling element (ball or rod) within the bearing. The basic dynamic load rating, C, is the load of a constant magnitude and direction, which a sufficiently large number of apparently identical bearings can endure for a basic rating life of one million revolutions. It's important to note that both the static and dynamic values are determined through ISO-Approved formulas. These formulas take into account several factors, including the design, internal geometry, material type, material quality, and lubrication type.

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# Technical • Life Calculation

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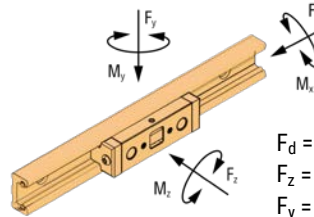
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## Terms, Definitions & Symbols

The following variables are used within the equations listed on the following pages:

|                     |  |
|---------------------|--|
| $F_{y \text{ app}}$ | = Force applied in the Y direction (radial force), N           |
| $F_{z \text{ app}}$ | = Force applied in the Z direction (axial force), N            |
| $M_{x \text{ app}}$ | = Moment applied about the X axis, N                           |
| $M_{y \text{ app}}$ | = Moment applied about the Y axis, N                           |
| $M_{z \text{ app}}$ | = Moment applied about the Z axis, N                           |
| $F_{\text{MAX}}$    | = Maximum allowable force in the Y direction (radial force), N |
| $F_{z \text{ MAX}}$ | = Maximum allowable force in the Z direction (axial force), N  |
| $M_{x \text{ MAX}}$ | = Maximum allowable moment about the X axis, N • m             |
| $M_{y \text{ MAX}}$ | = Maximum allowable moment about the Y axis, N • m             |
| $M_{z \text{ MAX}}$ | = Maximum allowable moment about the Z axis, N • m             |
| $D_a$               | = Rolling contact diameter, from product tables, mm            |
| $f_h$               | = Shaft (rail) hardness reduction factor                       |
| $f_l$               | = Required Lifetime (km) reduction factor                      |
| $f_r$               | = Reliability reduction factor                                 |
| $f_{ss}$            | = Short stroke reduction factor                                |
| $L_{10}$            | = Basic rating life, km (103 m)                                |
| $P_r$               | = Equivalent radial ( $F_y$ ) load, N                          |
| $s.f$               | = safety factor  |

Note: PBC Linear has chosen to depart from the nomenclature standards used by ISO. Instead, PBC Linear uses a convention that is more in line with other PBC Linear products. This ensures that all PBC Linear products use the same naming conventions, making it easier to compare multiple products from different product families. The Y direction (radial force) and Z direction (axial force) are dependant upon the orientation of the wheel bearing.



$F_d$  = Dynamic capacity (LC)  
 $F_z$  = Axial capacity  
 $F_y$  = Radial capacity  
 $M_x, M_y, M_z$  = Moment capacities

## Conversions

newton (N) • 0.2248 = lb.  
 (lb) meter • 0.0397 = inch  
 newton - meter (N-m) • 8.851 = in.-lb.

## Derivation

The lifetime formula within ISO 281 gives the life in millions of revolutions. The conversion from rotary life to linear life is done using the conversion factors listed in the following three equations. This derivation applies to both individual rollers and carriages. Lrev and Ldistance represent the lifetime of the bearing in revolutions and linear distance, respectively.

Note: Attention must be paid to units of measure, especially when considering products from different manufacturers. All of the lifetime formulas within this section yield results in kilometers; however, not all companies follow the same standard. Some companies may express life in meters or 100's of kilometers.

$$L_{\text{Distance}} [1 \cdot 10^5 \text{m}] = L_{\text{rev}} [1,000,000 \text{rev}] \cdot \left( 3.14 D_a \left[ \frac{\text{mm}}{\text{rev}} \right] \right) \cdot \left( \frac{1 \cdot 10^5 \text{m}}{1,000,000,000 \text{mm}} \right) \quad \text{Eq. 1}$$

$$L_{\text{Distance}} [1 \cdot 10^5 \text{m}] = L_{\text{rev}} \cdot (0.0314 D_a) \quad \text{Eq. 2}$$

$$L_{\text{Distance}} [\text{km}] = 100 \cdot L_{\text{rev}} \cdot (0.0314 D_a) = 3.14 \cdot D_a \cdot L_{\text{rev}} \quad \text{Eq. 3}$$



Link to whitepaper "The Facts About Roller Bearing Life Calculations"

# Technical • Life Calculation

Redi-Rail®

Commercial Rail

Hardened Crown Roller

V-Guide

Hevi-Rail®

## Individual Rollers – All products except Hevi-Rail Rollers

Most of the individual rollers within this catalog are Radial Ball Bearings. The following formulas should be used for all individual bearings except Hevi-Rail bearings (which are roller bearings). This formula calculates the basic rating life (L10 life), which does not take into account any reduction factors based upon the application.

$$L_{10} [km] = 3.14 \cdot D_a \cdot \left( f_L \cdot f_H \cdot f_{SS} \cdot \frac{F_{y_{max}}}{P_r} \right)^3 \cdot (f_R) \quad \text{Eq. 4}$$

$$P_r = X \cdot F_{y_{app}} + Y \cdot F_{z_{app}} \quad \text{Eq. 5}$$

The values for X & Y can be found using the table listed below.

## Values of X & Y for Radial Ball Bearing Life Formula

| Product                                    | $\frac{F_{z_{app}}}{F_{y_{app}}} \leq \epsilon$ |          | $\frac{F_{z_{app}}}{F_{y_{app}}} > \epsilon$ |             | $\epsilon$  |
|--|---|----------|--|-------------|-------------|
|  | X   | Y        | X  | Y           |             |
| <b>Commercial Rail (all sizes)</b>         | <b>1</b>  | <b>0</b> | <b>0.41</b>                                  | <b>0.87</b> | <b>0.68</b> |
| Hardened Crown Rollers                     | 1   | 0        | 0.41   | 0.87        | 0.68        |
| Integral-V (IVT) (Compact Linear Guides)   | 1   | 0.78     | 0.63   | 1.24        | 0.80        |
| Integral-V (IVT) (all other sizes & types) | 1   | 0.78     | 0.63   | 1.24        | 0.80        |
| Redi-Rail (all sizes & types)              | 1   | 0.78     | 0.63   | 1.24        | 0.80        |
| Steel-Rail (all sizes & types)             | 1   | 0.78     | 0.63   | 1.24        | 0.80        |
| V-Rail (all sizes)                         | 1   | 0.78     | 0.63   | 1.24        | 0.80        |



Redi-Rail®

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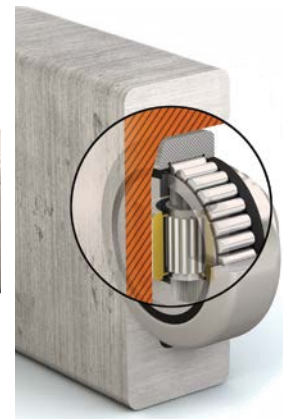
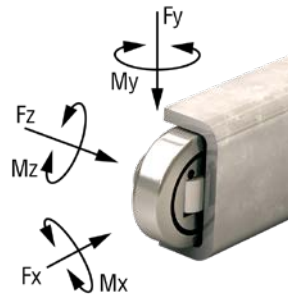
## Individual Rollers – Hevi-Rail Rollers

Hevi-Rail bearings are roller bearings, as opposed to radial ball bearings. The formulas are very similar to the formulas shown above, with only some minor changes.

Note: Hevi-Rail rollers are combined bearings. Essentially two bearings combined into one. Life calculations should be performed for both the radial and the axial bearing.

$$L_{L10} [km] = 3.14 \cdot D_a \cdot \left( f_L \cdot f_H \cdot f_{SS} \cdot \frac{F_{y_{max}}}{F_{y_{app}}} \right)^{\frac{10}{3}} \cdot (f_R) \quad \text{Eq. 6}$$

$$L_{a10} [km] = 3.14 \cdot D_a \cdot \left( f_L \cdot f_H \cdot f_{SS} \cdot \frac{F_{z_{max}}}{F_{z_{app}}} \right)^{\frac{10}{3}} \cdot (f_R) \quad \text{Eq. 7}$$



# Technical • Life Calculation

| Redi-Rail® | Commercial Rail | Hardened Crown Roller | V-Guide | Hevi-Rail® |
|------------|-----------------|-----------------------|---------|------------|
|------------|-----------------|-----------------------|---------|------------|

## Carriage Assemblies

Formulas for calculating the estimated lifetime for carriage assemblies are fundamentally similar to the calculations for the individual rollers. The most accurate method for determining the life of a carriage assembly is to create a free body diagram for the carriage and determine the axial, radial, and moment load applied to each individual roller. This method is cumbersome and is usually only required in the most severe of circumstances. In most cases, the carriage assembly can be treated as a rigid body and calculations can be completed based upon the load ratings for the entire carriage:



$$L_{10} [km] = 100 \cdot \left( f_L \cdot f_H \cdot f_{SS} \cdot \left( \frac{F_{y app}}{F_{y max}} + \frac{F_{z app}}{F_{z max}} + \frac{M_{x app}}{M_{x max}} + \frac{M_{y app}}{M_{y max}} + \frac{M_{z app}}{M_{z max}} \right) \right)^3 \cdot (f_R) \quad \text{Eq. 8}$$

| Redi-Rail® | Commercial Rail | Hardened Crown Roller | V-Guide | Hevi-Rail® |
|------------|-----------------|-----------------------|---------|------------|
|------------|-----------------|-----------------------|---------|------------|

## Safety Factor

All individual rollers and carriages are subject to use a balancing formula, which ensures an adequate product life. The following formulas should be used for all CRT products:

$$\text{Carriages } \frac{1}{s.f.} \geq \frac{F_{y app}}{F_{y max}} + \frac{F_{z app}}{F_{z max}} + \frac{M_{x app}}{M_{x max}} + \frac{M_{y app}}{M_{y max}} + \frac{M_{z app}}{M_{z max}} \quad \text{Eq. 9}$$

$$\text{Individual Bearings } \frac{1}{s.f.} \geq \frac{F_{y app}}{F_{y max}} + \frac{F_{z app}}{F_{z max}} \quad \text{Eq. 10}$$

Where the safety factor value can be determined using the following table.

## Recommended Safety Factor (s.f.)

| Duty       | Shock/Vibration | Reverse Frequency | Contamination | S.F.      |
|------------|-----------------|-------------------|---------------|-----------|
| Very Light | None            | Smooth & Low      | None          | 1.0 – 1.2 |
| Light      | Light           | Light             | Light         | 1.2 – 1.5 |
| Medium     | Medium          | Medium            | Medium        | 1.5 – 2.0 |
| Heavy      | Heavy           | High & Fast       | Heavy         | 2.0 – 3.5 |

Note: The table above contains suggested safety factors based upon the most commonly encountered adjustment criteria. Additional criteria may require raising the safety factor.

## Minimum Load Notice

It is possible to apply too small of a load to a bearing/carriage. In this case, there is a possibility of the outer ring slipping or the roller lifting off the track. This can cause unexpected vibration or skidding, which reduces the life of the bearing. Therefore, the following condition should be met under dynamic load conditions:

There is no minimum load requirement under static conditions.

$$\text{Minimum Dynamic Load} \rightarrow \frac{F_{y max}}{F_{y app}} \leq 50 \quad \text{Eq. 11}$$

# Technical • Life Calculation

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## Heavy Load Notice

It is also possible to over load the bearings. Extra-heavy loads can cause unexpected stress concentrations in the bearing or railway, which reduce the actual lifetime below the minimally acceptable level. These stress concentrations typically come from unexpected vibrations within the application or unexpectedly high preload forces caused by misalignment, damage, or thermal expansion. In these cases, a larger safety factor should be used.

**Use Caution** →  $P_{re} > 0.5 C_r$  Eq. 12

Note: Although typically applying to linear motion rolling bearings, ISO 14728-1 states that the above equation should be followed. It should be treated as a rule as opposed to a guideline.

If the product under consideration is a carriage (slider) assembly and  $P_r > 0.5 \cdot C_r$ , then it is recommended to consider the axial, radial and moment load applied to each individual roller to ensure each roller still has an adequate safety factor.

## Shaft/Rail Hardness Factor, $f_H$

It is possible to use a softer rail material in combination with PBC Linear CRT products; however, it is necessary to reduce the static and dynamic load capacities of each product. The reduced load capacity is known as the "Effective Load Capacity", which can be calculated using the formula below. The reduction factor,  $f_H$ , can be determined using the table below.

For easy reference, some of the most common materials have been plotted on the on the table below:

**Dynamic** →  $F_{Y\text{Eff}} = F_Y \cdot f_H$  Eq. 13

**Static** →  $F_{OY\text{Eff}} = F_{OY} \cdot f_H$  Eq. 14

## Approximate Comparison of Common International Materials

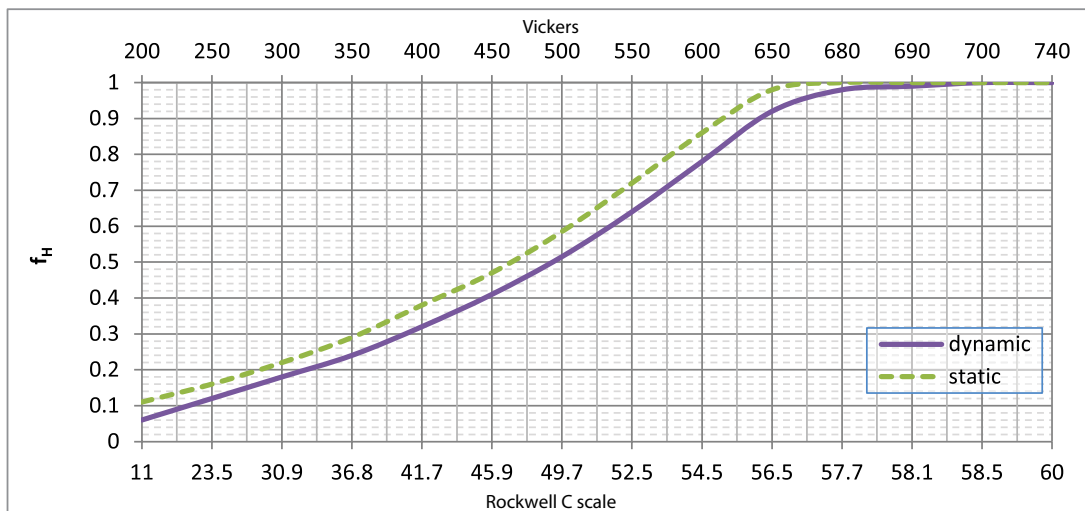
For easy reference, some of the most common materials have been plotted on the table below:

| # | TYPE            | EN NAME     | EN #   | ASTM/AISI | TYPICAL HARDNESS <sup>2</sup> | $f_H$    |
|---|-----------------|-------------|--------|-----------|-------------------------------|----------|
| 1 | Steel           | C60         | 1.0601 | 1060      | 60-62                         | 1.0      |
| 2 | Steel           | 52-3        | 1.0570 | 1024      | 19-22                         | 0.1      |
| 3 | Stainless Steel | X46 Cr13    | 1.4034 | 420       | 51-53                         | 0.7      |
| 4 | Stainless Steel | X90 CrMoV18 | 1.4112 | 440B      | 53-55                         | 0.8      |
| 5 | Stainless Steel | X105 CrMo17 | 1.4125 | 440C      | 59-61                         | 0.95-1.0 |

Note: The values listed in the above table should be considered for reference only. It is critical that individual suppliers are contacted to ensure an accurate hardness rating. Depending upon the supplier, "hardness" can actually be the minimum, maximum, or average value. The wrong interpretation can have unexpected consequences for the application. When given the choice, PBC Linear recommends using the "minimum hardness" when determining the reduction factor as this is the most conservative method.

1. Material Types may not be an exact match. PBC Linear has carefully reviewed the material standards and has determined that if there is not an exact match, the listed materials are the closest approximation. A material specialist should be consulted before translating one material type to another.
2. Different suppliers may have alternate ranges for material hardness, depending upon their heat treating process. Consult manufacturer's specifications for a more exact number/range.

Static & Dynamic Reduction Factors for Lower Raceway Hardness



# Technical • Life Calculation

Redi-Rail®

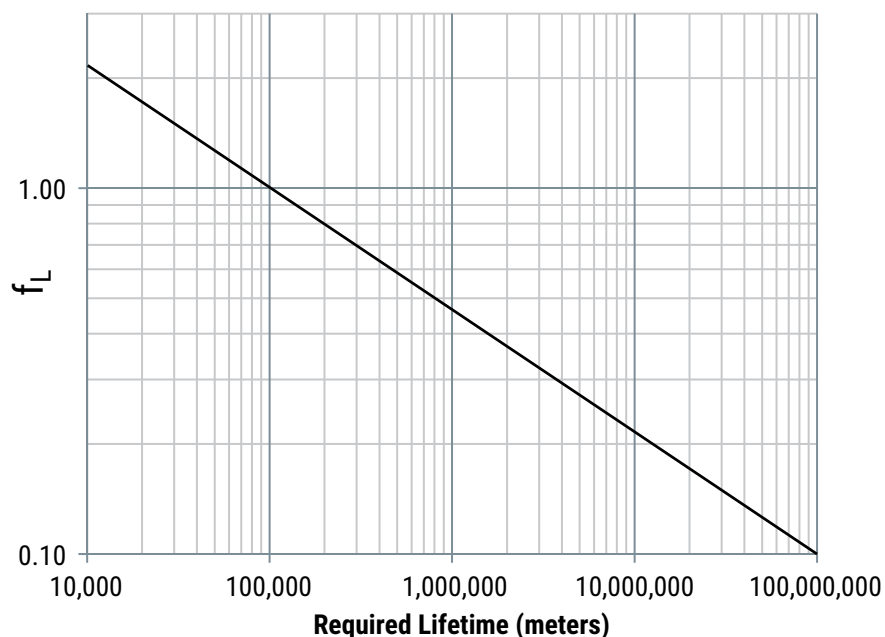
Commercial Rail

Hardened Crown Roller

V-Guide

Hevi-Rail®

## Required Lifetime (km) Factor, $f_L$



The standard lifetime formulas listed within this catalog describe an L10 life based upon 100 km, in accordance to the applicable ISO standards. Sometimes 100 km is either excessive or shy of the target life of a machine and the required lifetime needs to be adjusted. An appropriate adjustment factor can be found using the chart.

## Reliability Factor, $f_R$

| Reliability | $L_n$      | $f_R$ |
|-------------|------------|-------|
| 50%         | $L_{50}$   | 5.04  |
| 60%         | $L_{40}$   | 3.83  |
| 70%         | $L_{30}$   | 2.77  |
| 80%         | $L_{20}$   | 1.82  |
| 90%         | $L_{10}$   | 1.0   |
| 95%         | $L_5$      | 0.64  |
| 96%         | $L_4$      | 0.55  |
| 97%         | $L_3$      | 0.47  |
| 98%         | $L_2$      | 0.37  |
| 99%         | $L_1$      | 0.25  |
| 99.2%       | $L_{0.8}$  | 0.22  |
| 99.4%       | $L_{0.6}$  | 0.19  |
| 99.6%       | $L_{0.4}$  | 0.16  |
| 99.8%       | $L_{0.2}$  | 0.12  |
| 99.9%       | $L_{0.1}$  | 0.093 |
| 99.92%      | $L_{0.08}$ | 0.087 |
| 99.94%      | $L_{0.06}$ | 0.080 |
| 99.95%      | $L_{0.05}$ | 0.077 |

The L10 Life Formulas are a statistical probability formula with a success rate of 90%. Sometimes an L10 life (90% success) is just not good enough and the formulas need to be modified in order to have a higher probability of success. In this case, choose the desired reliability rate and insert the  $f_R$  value into the life equation.

# Technical • Life Calculation

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Commercial Rail

Hardened Crown Roller

V-Guide

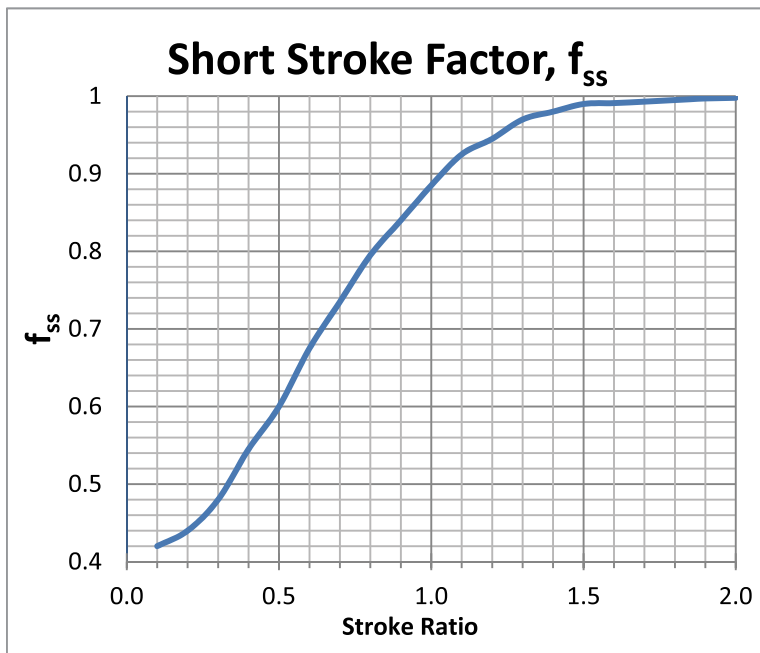
Hevi-Rail®

## Short Stroke Factor, $f_{ss}$

In the case that the travel distance is low, a short stroke reduction factor must be included. In general, this factor only applies when the stroke is less than 2x the carriage length. In the case of individual bearings, use two full revolutions of the bearing.

$$\text{Stroke ratio, carriage (slider)} = \frac{\text{stroke [mm]}}{\text{carriage length [mm]}} \quad \text{Eq. 15}$$

$$\text{Stroke ratio, individual bearing} = \frac{\text{stroke [mm]}}{\pi D_p \text{ [mm]}} \quad \text{Eq. 15}$$



# Technical • Installation

## Redi-Rail®

## Commercial Rail

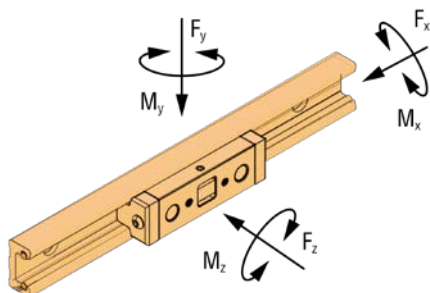
## Hardened Crown Roller

## V-Guide

## Hevi-Rail®

### General Installation

As a general rule, all of the products within the catalog have a higher radial ( $F_y$ ) than axial ( $F_z$ ) load capacity. Whenever possible, designers should attempt to orient the bearings so the primary applied load is in the radial direction.



### Commercial Rail

Commercial Rail is typically used in applications which require low to moderate accuracy. It is generally not necessary to use any advanced manufacturing or assembly techniques to secure this rail system into place.

**Note:** If an assembly plan requires Commercial Rail to be installed with dial indicators, calipers, or other sensitive measuring equipment, then likely this product has probably been over-specified for an application. Consider using a more accurate product for these applications, such as the V-Guide System, Redi-Rail, Integral-V (IVT), or Steel Rail.

### Hardened Crown Roller Rail

**Note:** If an assembly plan requires Hardened Crown Roller rails to be installed with dial indicators, calipers, or other sensitive measuring equipment, then it is likely this product has probably been over-specified for an application. Consider using a more accurate product in these applications, such as the V-Guide System, Integral-V (IVT), Redi-Rail, or Flexible Steel Rail.

### Redi-Rail

The Redi-Rail product is very versatile and can be used in applications that require low accuracy or moderate-high accuracy. In applications that require low accuracy, no special installation, and alignment procedures are needed. In applications that require moderate to high accuracy, use advanced assembly techniques similar to those used for installing profile rail guideways.

**Note:** Refer to the PRT (Profile Rail Technology) catalog for more detailed information related to advanced assembly techniques.

### Hevi-Rail

Hevi-Rail is typically used in applications that require moderate accuracy. There are two common methods for installing Hevi-Rail: Welding & Clamp Flanges.

#### Welding

The preferred method of welding Hevi-Rail, Flange Plates, and Hevi-Rail Clamp Flanges is MIG Welding. Please follow the guidelines listed below when MIG welding Hevi-Rail, Flange Plates and Hevi-Rail Clamp Flanges.

1. Use a metal brush or grinder to remove rust or paint from surface to be welded.
2. Bevel joint edges on metals thicker than 3/8" to ensure the weld fully penetrates to the base of the metal. (HVR-2, HVR-3, HVR-4, HVR-5 HVR-6, HVRI-08, HVRI-09, HVRI-10, and HVRI-11).
3. Ensure that grounding clamp is engaged in clean metal.
4. When welding HVR-S, HVR-0, HVR-1, and HVRI-07 sections of Hevi-Rail it is recommended to use 0.03" diameter wire. A preferable grade wire for mild steel is ER70S-3.
5. When welding thick sections of Hevi-Rail, it is recommended to use 0.035"-0.045" ER70S-3 wire. Weld at a higher heat level to obtain a deep penetration. This is recommended for HVR-2, HVR-3, HVR-4, HVR-5 HVR-6, HVRI-08, HVRI-09, HVRI-10, and HVRI-11.
6. A 75% Argon/25% Carbon Dioxide mix is a preferable general purpose shielding gas when welding mild steels like Hevi-Rail.
7. Know your load calculations, when in doubt meet with your structural or mechanical engineer.
8. Destructive testing facilities are recommended for testing weld strength. Periodic destructive testing ensures that the welding equipment and welding practices are yielding safe and strong welds.
9. Never weld a mild steel Hevi-Rail product to a dissimilar metal such as cast iron or stainless steel.

#### Clamp Flanges

When using bolts to hold a Clamp Flange to Hevi-Rail HVR1, HVR-2, HVR-3, HVR-4, HVR-5, or HVR-6, it is recommend to drill a detent in the top of the rail where the screw seats. Many customers use a drill point smaller than the minor diameter of the tap diameter to put a point in the rail. This is preferred in systems that have vibrations and harmonics in its environment. Some customers use bolts to align and assemble the system, then weld the clamp to the rail.

# Technical • Installation

## Redi-Rail®

## Commercial Rail

## Hardened Crown Roller

## V-Guide

## Hevi-Rail®

### V-Guide

V-Rail is typically used in applications that require low to moderate accuracy. The installation accuracy is primarily limited by the accuracy of the mounting surface. It is possible to successfully install V-Rail onto as-extruded bars and plates, or to rolled metal bars and plates. These materials typically do not have very tight dimensional, parallelism, flatness, and straightness tolerances. The loose tolerances add to the overall tolerance stack-up, which reduces the installation accuracy.

A higher grade of accuracy can be achieved by machining the mounting plate, typically through a milling or grinding process. It is possible to achieve an accuracy rating as high as  $\pm 0.025$  mm ( $\pm 0.001$  in.) using machine tool design and assembly techniques. In this case, the mounting surface must be meticulously prepared, and reference edge or dowel pins should be used for alignment purposes.

**Note:** Integral-V (IVT) products eliminate this alignment process. If an application requires two parallel rails, PBC Linear highly recommends the consideration of the IVT products. Customers have reported significant Total Installed Cost (TIC) savings that have been achieved through the use of IVT products.

### General Notes

#### Handling

Proper handling of PBC Linear products is critical to ensure specified product performance, product life, and to prevent accidental injury. Some products come from the factory with a clearance type preload. These carriages will freely slide if the rail is not kept horizontal. Special attention must be paid when installing the rail overhead or in a vertical orientation.

Special care must also be given to long length units. Single point lifting some products may cause enough bend as to result in permanent, plastic deformation to the railway. Always use suitable lifting equipment that provides enough support to minimize deflection.

#### Storage

Proper storage is critical in order to maintain an adequate product shelf life. If immediate installation is not possible or practical, it is best to store the product within the package provided by (or designated by) PBC Linear. The product and package should be stored in a horizontal orientation and environmental extremes (high temperature, low temperature, and high humidity) should be avoided. It may be necessary to lubricate steel components during prolonged storage in order to prevent corrosion.

### Securing Fasteners

PBC Linear makes no specific recommendation as to whether or not thread-locking fluid (i.e. Loctite®), lock nuts, lock washers, etc., should be used within a given application. Sound engineering fundamentals and company policies should dictate the use of anti-vibration components and technology. Some common reference materials include, but are not limited to:

- Your company's policies and/or engineering specifications
- Marks's Standard Handbook for Mechanical Engineers, published by McGraw-Hill (English)
- Machinery's Handbook, published by Industrial Press (English)
- Roloff/Matek Maschinenelemente, published by Vieweg (German)

### Fastener Quantity

It may not be necessary to use a fastener within every supplied fixing hole. This is especially true for applications carrying a light load (high factor of safety). Engineering statics equations can be used to determine the amount of deflection within a rail if not all fixing holes are used. Modern tools, such as FEA, can also be used to speed up this process.

### Welding

The recommendations and guidelines listed herein are recommendations only. Always follow your specific company's policies, welding equipment manufacturer's instructions, guidelines established by national standards agencies (i.e. ANSI/DIN) and city/state/federal laws or civil guidelines related to proper welding practices. Improper application or installation of PBC Linear products can result in property damage, death, or serious bodily injury.

**Note:** Improper installation of carriages with spring-loaded lubricators can permanently damage the lubricator material. Damage caused by improper installation is not covered by PBC Linear warranty.

### Initial Lubrication

After installation, follow the initial lubrication instructions located within this catalog or at [pbclinear.com](http://pbclinear.com). All products are shipped with a preservative material, which should not be considered a true performance lubricant. Lubricant should be added before initial use.

### Painting/Powder Coating

Most PBC Linear products can be painted or powder coated after installation to match the aesthetic appearance of the parent structure. It is highly recommended that the bearing's raceway be masked during this process. These coatings will typically not withstand the pressure of a typical operation and will flake off. These flakes will act as bumps causing the rollers to experience unplanned vibration. This can cause an unexpected shortening of the life of the rollers/carriage.

# Technical • Lubrication

## Redi-Rail®

## Commercial Rail

## Hardened Crown Roller

## V-Guide

## Hevi-Rail®

### Roller Lubrication

All smaller rollers (in the Redi-Rail, IVT, V-Guide, Commercial Rail, Hardened Crown Roller families, and smaller diameter Hevi-Rail bearings) are lubricated internally for long life. No additional lubrication is necessary. The rollers are sealed (or shielded) against the operating environment to prevent egress of lubricant, and prevent ingress of contaminants. Some larger rollers (in the Hevi-Rail family) are supplied with a grease access point and can be re-lubricated using a zerk fitting.

### Raceway/Guideway Lubrication

To ensure long life, it is necessary to have a thin film of lubrication on the Raceway/Railway at all times. When properly applied, lubrication:

- Reduces wear
- Reduces stress on the contact surfaces
- Reduces friction (and therefore heat buildup)
- Allows for operation at specifications in this catalog (de-rating is required for un-lubricated applications)
- Helps protect the metal surfaces against corrosion (rust and fretting corrosion)

### Lubrication Type

Technical, environmental, ecological, and economic factors will determine whether oil or grease should be used in an application. One of the most significant factors in the lubrication selected is the environmental conditions. If extreme conditions are expected, it is highly recommended that a representative from a lubrication company is consulted. This includes heavy contamination when the expected particle size is smaller than 0.1 mm (0.005 in.) as small particles can more easily bypass seals and wipers.

CAUTION! The compatibility of lubricants must always be



checked! This check should be done under both static and dynamic conditions and within the operating environment. Some lubricants may

have unexpected, negative reactions with the plastics, elastomers or non-ferrous metals within the products. It is possible to draw upon previous and practical experience or guidelines from the lubricant manufacturer. When in doubt, consult the lubricant manufacturer.

### Initial Lubrication (during installation)

PBC Linear Guides and Raceways are shipped with a preservative lubrication applied to the raceway. During installation, it is necessary to apply additional lubrication. Provided there are no application conflicts, PBC Linear recommends high quality lithium soap grease as the initial lubricant. This grease should be applied to the entire raceway, not just the portion used during normal operation. Oil or grease may be used for re-lubrication.

**Note:** Coated/Plated rails, Commercial Rail, Hardened Crown Roller, and Hevi-Rail rails are typically shipped without any preservative lubrication. See the Hevi-Rail section for more details: sandblast and lightly oiled option is available for Hevi-Rail.

### Periodic Lubrication/Maintenance

The lubrication interval is dependent on many operating and environmental conditions, such as load, stroke, velocity, acceleration, mounting position/orientation, type of lubrication used, temperature, humidity, UV exposure, etc. The actual lubrication interval should be determined by tests conducted under actual application conditions.

While the actual lubrication intervals are application specific and determined only through testing, the following guidelines can typically be used as a starting reference point under normal conditions:

- Re-lubrication every 1,000 km; 50,000 cycles or six months (whichever occurs first).

# Technical • Lubrication

## Redi-Rail®

## Commercial Rail

## Hardened Crown Roller

## V-Guide

## Hevi-Rail®

### Oil Filled Polymer Lubricator

Some PBC Linear products offer a high quality polymer lubricator. PBC Linear uses an advanced, oil filled porous polymer, which has been tested to show better performance and longer life than similar wiper/lubricators made of oil or grease filled felt. In some applications, this special lubricator will last the life of the application without additional re-lubrication.

This lubricant within the polymer is NSF Registered for both H1 & H2 applications (Direct and Indirect contact with food). It can also be used for wash down and industrial applications. The lubrication within the polymer contains corrosion inhibitors, anti-oxidants, and extreme pressure (E.P.) additives. The table below shows some specific properties for the lubricant.

### Properties for Lubrication in Advanced Oil-Filled Plastic Properties for Lubrication in Advanced Oil-Filled Plastic

| Upper Temp Limit | Lower Temp Limit | Specific Gravity | Viscosity at 40°C cSt | Viscosity at 100°C CST |
|------------------|------------------|------------------|-----------------------|------------------------|
| 99° (210°F)      | -40° (-40°F)     | 0.86             | 150                   | 16.5                   |

### Used Lubricants

Used lubricants should be disposed of using environmentally-friendly methods. Most lubricant manufacturers have guidelines regarding their allowable storage, use, and disposal. In addition, some countries have regulations regarding storage, use, and disposal of lubricants for occupational safety and/or environmental protection. Furthermore, some companies may have adopted internationally accepted quality and standards policies (i.e. ISO14001), which will further regulate the use of lubricants within an application.

These guidelines and regulations must be followed. Care should be exercised as to not specify a lubricant which is forbidden.

### Lubrication Failure

Contamination and lack of lubrication are the two primary causes of (ball based) linear guide failures. Lack of lubrication will cause fretting corrosion, which can cause permanent system damage and eventually lead to system failure. As it applies to this product, fretting corrosion is a form of damage caused as a combination of corrosion and abrasive wear. Fretting corrosion can typically be seen as a reddish discoloration on either mating raceway (track or roller). Fretting corrosion can sometimes be confused with rust. Both are signs that additional lubrication is necessary and the re-lubrication period must be decreased.

### Operation in an Un-Lubricated State

While not recommended, it is possible to run most systems without lubrication; however, there will be significant reductions to maximum load, maximum speed, and expected life. The table below shows that a typical un-lubricated system will have a significantly reduced maximum load and a reduced maximum speed when compared to a properly lubricated system.

### Typical Reductions for Max Load & Speed for Un-Lubricated Systems

| Product |           |     | Lubricated | Un-Lubricated | Reduction |
|---------|-----------|-----|------------|---------------|-----------|
| A       | Max Load  | kg  | 100        | 25            | 75%       |
|         | Max Speed | m/s | 2          | 1.5           | 25%       |

In addition to significant reductions in maximum load and speed, un-lubricated system will also experience an extreme reduction in expected life. The table below shows the expected life for both a lubricated and un-lubricated system for two different products with two different applied loads. The approximate reduction in lifetime has also been calculated.

### Typical Life Reductions for Un-Lubricated Systems

| Product |                |    | Lubricated | Un-Lubricated | Reduction |
|---------|----------------|----|------------|---------------|-----------|
| B       | Applied Load 1 | kg | 45.4       | 45.4          | –         |
|         | Life 1         | m  | 5,410,200  | 88,900        | ≈ 98%     |
|         | Applied Load 2 | kg | 22.7       | 22.7          | –         |
|         | Life 2         | m  | 22,860,000 | 533,400       | ≈ 98%     |
| C       | Applied Load 3 | kg | 45.4       | 45.4          | –         |
|         | Life 3         | m  | 50,800,000 | 863,600       | ≈ 98%     |
|         | Applied Load 4 | kg | 90.7       | 90.7          | –         |
|         | Life 4         | m  | 8,382,000  | 152,400       | ≈ 98%     |

Note: Actual performance will vary depending upon specific application conditions. PBC Linear has removed the actual product name from the examples listed above as the results may not be repeatable, depending upon specific application conditions. While these values are typical, specific reductions should be determined by tests conducted under actual application conditions.

# Technical • General

Redi-Rail®

Commercial Rail

Hardened Crown Roller

V-Guide

Hevi-Rail®

## Operating Temperature

The Cam Roller products shown in the catalog have a wide operating temperature limit. All of the products within this catalog can be used within the following range: -20°C to +80°C (-4°F to 176°F). For applications outside of this range, first refer to the specifications for individual products. If a wider range is still needed, please contact our applications engineering group using the contact information below.

The temperature range for these products is limited by the lubricant, engineered polymer wipers, and composite cover materials. In most cases, changing the lubricant or the engineered polymer will extend the operating temperature limit for the product.

## Velocity & Acceleration

For maximum velocities, check the product specifications. The maximum velocities will range from 0.76 m/s up to 12 m/s. Higher speeds may be possible, but may not be sustainable. Please contact our applications engineering group for sustained speeds above 12 m/s (33 ft/s).

Unless otherwise noted, the maximum possible acceleration of all CRT products is approximately 5 G's (50 m/s<sup>2</sup>, 160 ft/s<sup>2</sup>). Higher accelerations are possible, but may not be sustainable. Please contact our applications engineering group for sustained accelerations above 5 G's.

## Contact Information

If you need to contact our applications engineering group, please use one of the following methods:

Phone: +1.800.962.8979 (inside USA)

Phone: +1.815.389.5600 (outside USA)

Email: [application.engineering@pbclinear.com](mailto:application.engineering@pbclinear.com)



## Safety guidelines

### Product Safety

PBC Linear products are designed and manufactured to the most current level of technology and research. If the bearing (or linear guide) arrangement is designed, handled, installed, and maintained correctly, then they do not give rise to any known or direct hazards. Misapplication, improper handling, improper installation, or improper maintenance may lead to premature product failure, which may have unintended consequences.

### Read & Follow Instructions

This publication describes standard products. Since these are used in numerous applications, PBC Linear cannot make a judgment as to whether any malfunctions will cause harm to persons or property. It is always, and fundamentally, the responsibility of the designer and user to ensure that all specifications are observed, and that all necessary safety information is communicated to the end user. This applies in particular to applications in which product failure and/or malfunction may constitute a hazard to human beings.

### Symbols

This publication uses several hazard, warning and notification symbols which are defined in accordance to ANSI Z535.6-2006.

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A Pacific Bearing Company

**Engineering Your Linear Motion Solutions**



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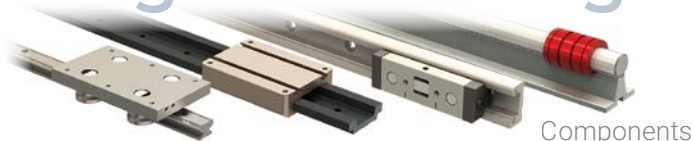
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## Range of Offerings



Components



Mechatronics

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