Limiting Speeds

The following limiting speed information is provided for reference only. For actual speeds, use the REALI-DESIGN™ software found on our website, www.kaydonbearings.com.

The determination of maximum safe operating speeds is largely empirical. Various complex factors play a part in limiting the speed of rotation, some of which are:

- Bearing diameter
- Ratio of bearing diameter to cross-section
- Bearing type and internal configuration
- Ratio of ball groove radius to ball diameter
- Bearing internal fit-up (diametral clearance or preload)
- Operating contact angle(s)
- Bearing precision (runouts)
- Ball separator material and design
- Precision of mount (roundness, flatness under load)
- Lubrication
- Ambient temperature and provision for heat dissipation
- Seals
- Loads
- Life requirement

While precise speed limits cannot be set, experience in actual applications and in the KAYDON test laboratories can serve as a basis for setting general limits. Figure 4-10 takes into account some of the factors and assumes proper installation and adequate provision for heat dissipation. These limits are based upon achieving the full service life of 1,000,000 revolutions. If a shorter life is acceptable, higher speeds may be tolerated, except for bearings using formed wire and helical spring separators.

For speeds near or over the limits in the table, special attention must be given to lubrication and heat. Greases should be of types specially formulated for high speed bearings. Frequency of regreasing must be adequate to insure presence of lubricant at all times. If oil is used, viscous drag should be minimized by controlling the level, using slingers and/or metering small amounts as a liquid or mist. Windage effects at high speeds can make the introduction of oil to the critical surfaces very difficult, and the design of the lubrication system then becomes important. Please consult lubrication manufacturer.

Generally speaking, operating temperature will be limited by the allowable maximum temperature for the lubricant. If, however, bearing temperature is expected to exceed 250°F for extended periods, the bearings should be given stabilization treatment by KAYDON. This treatment will permit operation at temperatures up to 400°F.

While maximum temperature is important, consideration must also be given to possible temperature differential across the bearing. Generally, heat is lost through the housing at a higher rate than through the shaft. The housing fit and the bearing internal clearance before installation must be sufficient to allow for this as well as for the shaft fit if the necessary running clearance is to be realized.

Examples of Limiting Speed Calculations

Example 1 (Standard Bearing)

Limited speed calculation for bearing part number KG040XP0.

Conditions: light thrust loads (<20%), grease lubrication.

From Figure 4-8: slimness symbol = I

From Figure 4-9: derating factor = 1.0

From Figure 4-10: Type X; Separator P; Grease; Class 1; Charted figure = 9

Calculation: $N = \frac{(1.0)\,(9)\,(1000)}{4} = 2{,}250$

Example 2 (High Performance Bearing)

Limiting speed calculation for bearing number KD100AH6.

Conditions: loading at 25%, oil lubrication

From Figure 4-8: slimness symbol = II

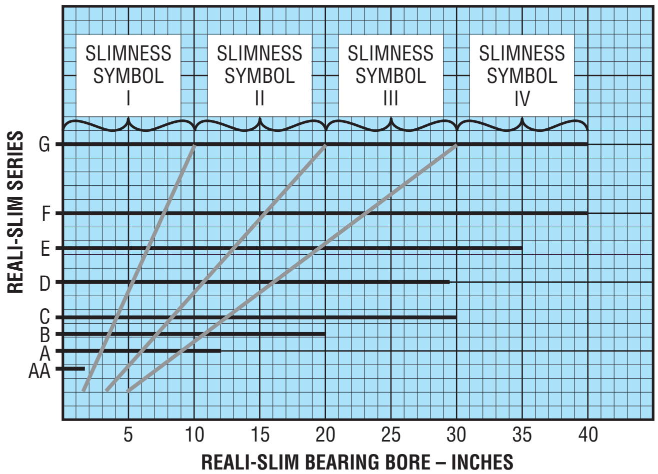
From Figure 4-9: derating factor = 0.9

From Figure 4-10: Type A; Separator H; Oil; Class 6; Charted figure = 32

Calculation: $N = \frac{(0.9)\,(32)\,(1000)}{10} = 2{,}880$

LIMITING SPEEDS (continued)

Figure 4-8 - Slimness Symbol (S_s)



Limiting Speeds for Unsealed Lightly Loaded REALI-SLIM® Ball Bearings

$$\text{Limiting Speed (N)} = \frac{(F_l)\,(C_f)\,(1000)}{D}$$

where

D = Bearing bore in inches

N = RPM

Figure 4-9 - Derating Factor (F_l)

For bearings loaded to following percent of dynamic rating	Multiply DN values by following factors
20	1.0
33	.9
50	.8
67	.7
100	.5
150	.2

Figure 4-10 - Charted Figures (C_f)

Bearing Type	Load Conditions	Separator Type	PRECISION CLASS AND LUBRICATION																			
			CLASS 1, 3 & 4								CLASS 6											
			GREASE				OIL				GREASE				OIL				OIL MIST			
Slimness Symbol from Figure 4-8			I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
C with Diametral Clearance	Radial	P, L, X	15	12	9	6	21	18	15	12	21	18	15	12	27	24	21	18	30	27	24	21
		K	20	16	12	8	28	24	20	16	28	24	20	16	36	32	28	24	40	36	32	28
A Spring Loaded or Axially Adjusted	Radial and/or Thrust	R	15	12	9	6	21	18	15	12	21	18	15	12	27	24	21	18	30	27	24	21
		G, H	20	16	12	8	28	24	20	16	28	24	20	16	36	32	28	24	40	36	32	28
		M	8	6	5	3	11	9	8	6	11	9	8	6	14	12	11	9	15	14	12	11
X with Diametral Clearance	Thrust Only	P, L, X	9	8	7	6	11	10	9	8	11	10	9	8	14	12	11	9	15	14	12	11
	Radial Only or Combined Loading	P, L, X	3.0	2.5	2.0	1.5	4	3.5	3	2	4	3.5	3	2	4.5	4	3.5	3	5	4.5	4	3.5

Section 4–Separators, Balls, Performance

Torque Considerations

Torque, as it applies to bearings, is defined as the moment required to turn the rotating race with respect to the stationary race.

Usually the torque requirement of a ball bearing is only a small part of the demand of a mechanical system. In many REALI-SLIM® bearing applications, however, masses and consequent inertias are slight and the amount of work being done is not great. In such cases, it may be important to know as accurately as possible how much turning effort must be provided.

Many factors contribute to the resistance to rotation of a lightly loaded anti-friction bearing, and most of this resistance comes from the more unpredictable ones—separator drag; viscous drag of the lubricant; minute deviations from true geometry in the balls, race ways, and mounting surfaces of bearing, shaft, and housing; internal fit-up of the bearing; and the presence of contaminants.

Bearings can be furnished to a maximum torque level specification.

In the selection of the lubricant and lubricating system, their effects on torque should be kept in mind. To be considered are operating temperatures; speeds of rotation; type, viscosity and quantity of lubricant. All are major factors in determining lubricant drag. Please consult lubrication manufacturer.

In tolerancing the shaft and housing it is important to set limits for out-of-roundness and out-of-flatness of the bearing seats. For normal requirements a good rule of thumb is to use the bearing radial and axial runout tolerances as the respective limits. For critical torque applications, closer tolerances should be specified since even a very small amount of localized internal preload (negative clearance) will create surprisingly large ball loads and consequent high torque. Where torque must be minimized it is important to limit out-of-roundness of housing or shaft to values which will insure against complete loss of internal clearance.

Cleanliness is extremely important in maintaining uniformity of torque as well as a low level of torque. Very small amounts of microscopic particles of lint, dust, and other common contaminants can cause bearing torque to vary several hundred percent in just a few degrees of rotation. For this reason bearings should be kept in their original unopened package until time for installation. Every effort should be made to protect them from foreign matter, whether or not torque is critical.

The accompanying charts show approximate torque levels of REALI-SLIM® bearings under stated conditions. Estimates can be furnished for more unusual situations. Information submitted should contain all operating conditions of load, speed, lubricant, and environment including temperature together with a print of the intended mounting, showing materials and radial sections. If a limit has been set on permissible system error in terms of axis deviation—radial translation, axial translation, or angular rotation (page 102) — this information should also be submitted.

Additional processing is used to achieve the lowest possible torque levels. High precision races and balls, super-finished ball tracks, and precisely set internal fit-ups assure optimum performance.

- Low-torque ball separators
- Clean-room assembly
- Factory-lubricated bearings
- ABMA Grade 10 balls
- Super-finish ball track

Materials

Races	AISI 52100 (Precision Class 6)
Balls	AISI 52100 (Grade 10)
Cage (Type A)	PTFE or Vespel® toroid ball spacers
Cage (Types C, X)	Slugs

Starting Torque vs. Load

Computer generated torque curves for mounted REALI-SLIM® bearings can be provided by KAYDON Product Engineering

Figure 4-11

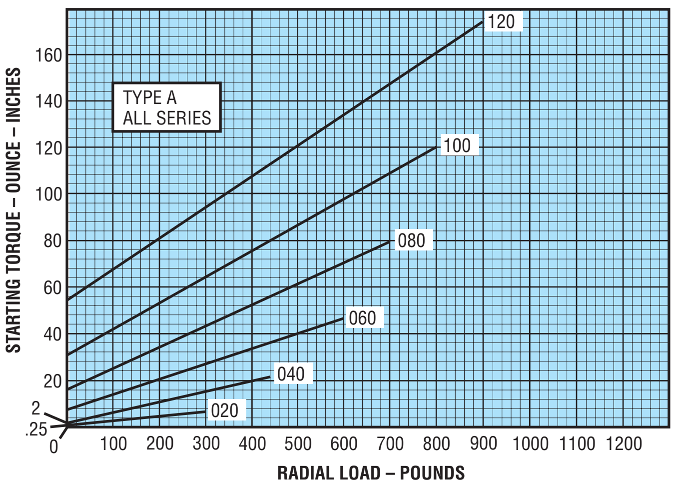


Figure 4-13

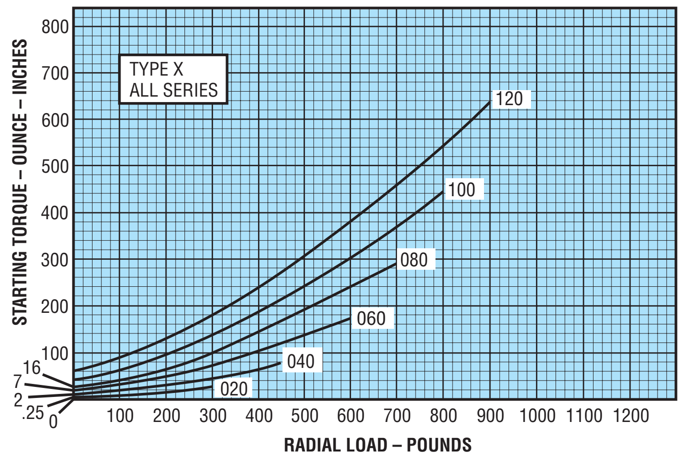


Figure 4-12

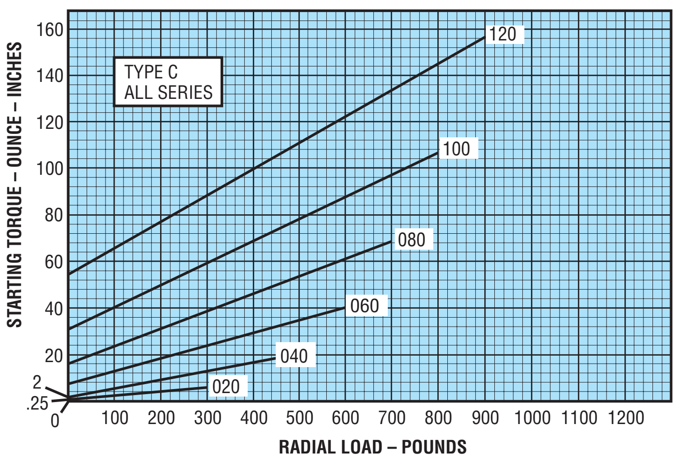
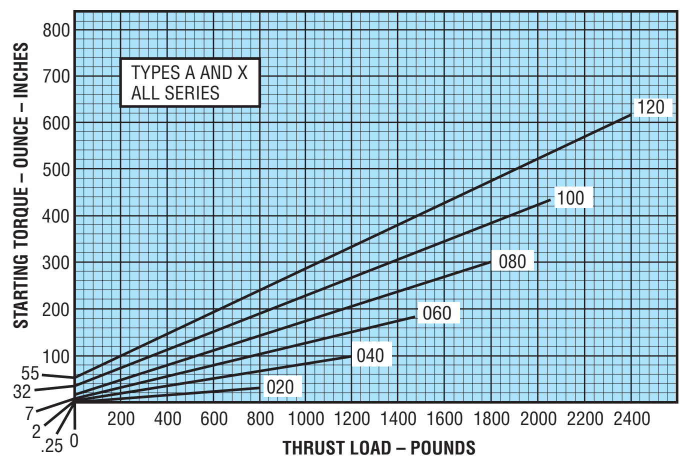


Figure 4-14



Notes Applying to These Charts

1. Values shown are statistical ratings* based on:
   - KAYDON Precision Class 1 bearings with some internal clearance remaining after installation
   - A rigid mounting, round and flat within respective radial and axial bearing runout limits
   - Light oil lubrication
   - Room temperature
2. Running torque at speeds up to 10 RPM usually averages from 25 to 50% of starting torque, and increases with increasing speed to as much as 200% at maximum allowable diametral clearance (page 103).
3. Interpolate for intermediate sizes.
4. Curve number indicates bearing bore in tenths of an inch.

*Usually not more than 10% of a group of bearings will have torque demands higher than those shown.

Bearing Axis Deviation Due to Clearance And Deflection

REALI-SLIM® bearings are often used in applications where the position of a rotating part relative to the stationary structure is critical. Knowledge of the displacement of the axis of rotation and the factors contributing to it are thus important.

The axis of rotation can be displaced from its true position in three ways—radially, axially, and angularly. These deviations are referred to as radial translation, axial translation, and tilt (angular rotation) respectively.

In addition to the obvious effects of bearing runout, total deviation of bearing axis in any one of the above conditions is due to the effects of bearing diametral clearance and elastic deflection (deformation) at the ball or roller contacts. The diametral clearance after installation changes due to the combined effects of external fitting practice, differential thermal expansion or contraction of the bearing races and mounting structures, and relative rigidity of the races and mating parts.

Elastic deflection at the ball or roller contacts results from the externally applied bearing loads and is influenced by ball or roller diameter, race groove radius, raceway diameters, and contact angle.

The following three equations are given to aid in determining displacement. The internal diametral clearance (DC) must be calculated or approximated. The remaining independent variables can be obtained from the graphs on pages 104 through 109.

$$RT = RD + \frac{DC}{2}$$

$$AT = AD + \frac{AC}{2}$$

$$AR = MD + AC/PD$$

Where:

RT	=	Radial Translation	– in inches
AT	=	Axial Translation	– in inches
AR	=	Angular Rotation	– in inches/ inch or radians
RD	=	Radial deflection due to radial load	– in inches
AD	=	Axial deflection due to axial load	– in inches
MD	=	Moment deflection due to moment load	– in inches/ inch or radians
DC	=	Diametral clearance	– in inches
AC	=	Axial clearance	– in inches
PD	=	Pitch diameter $\frac{\text{O.D. + Bore}}{2}$	– in inches

The equations may be used in applications where the radial, axial, or moment load is applied singly or where one type of loading predominates. For assistance in selecting REALI-SLIM® bearings, contact KAYDON Engineering.

Computer-generated reports and graphs for REALI-SLIM® bearings are available from KAYDON engineering and from our REALI-DESIGN™ computer software, available for download at www.kaydonbearings.com.

Axial Clearance vs. Diametral Clearance

Figure 4-15

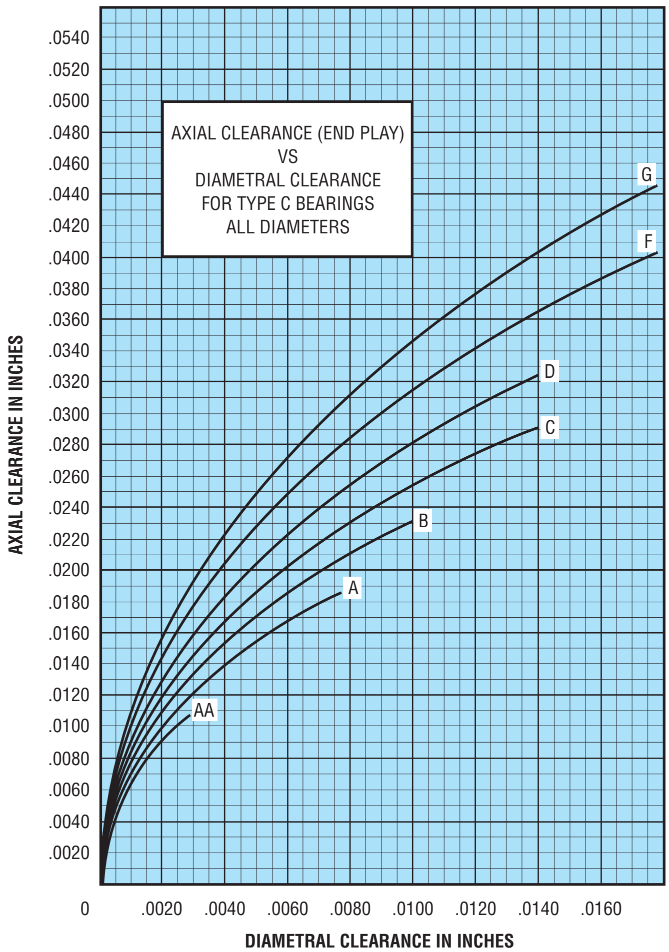
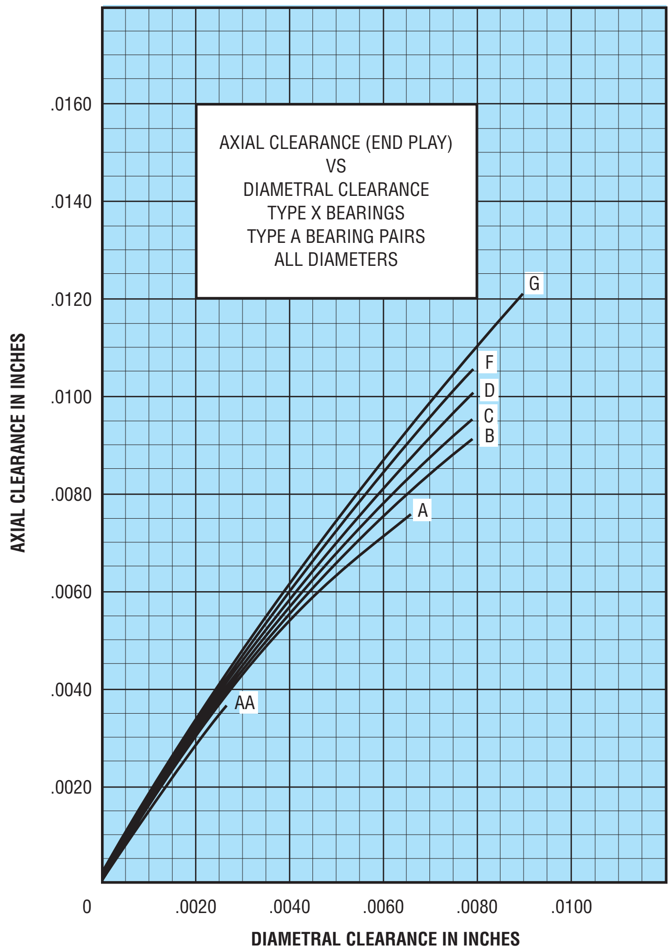


Figure 4-16



Section 4–Separators, Balls, Performance

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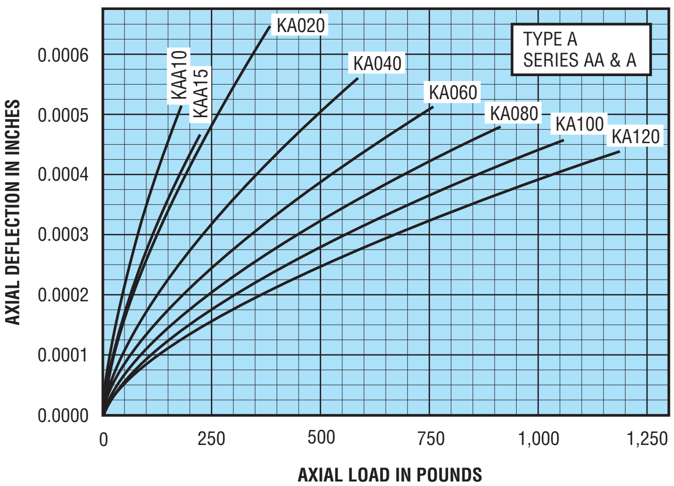
Website: www.kaydonbearings.com

Axial Deflection vs. Axial Load

Type A Angular Contact

For more detailed information, use KAYDON REALI-DESIGN™ software

Figure 4-17



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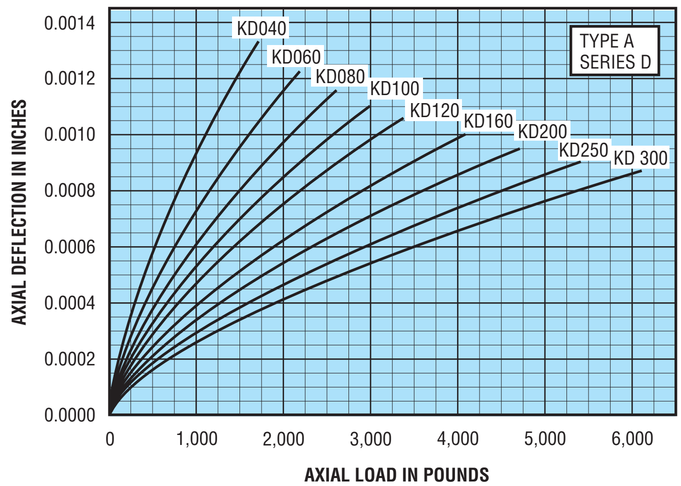

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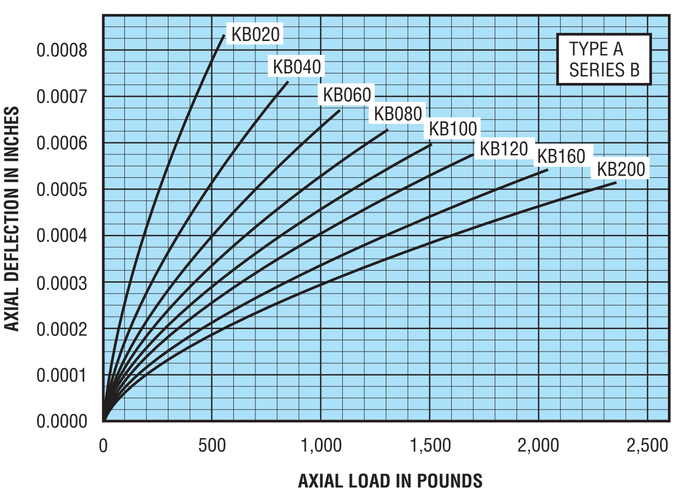

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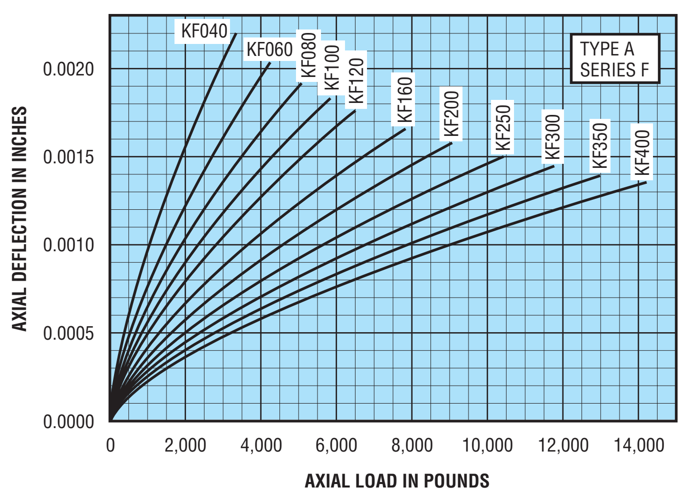

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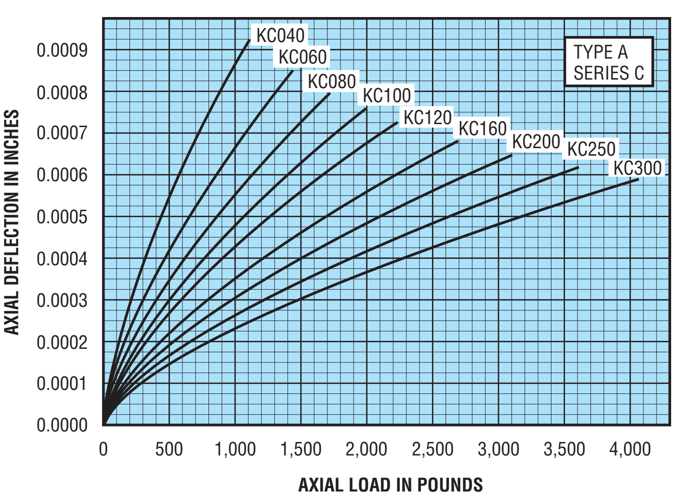

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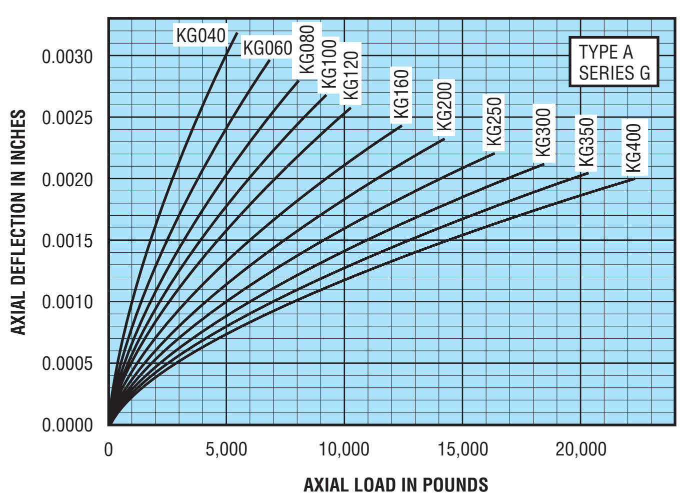
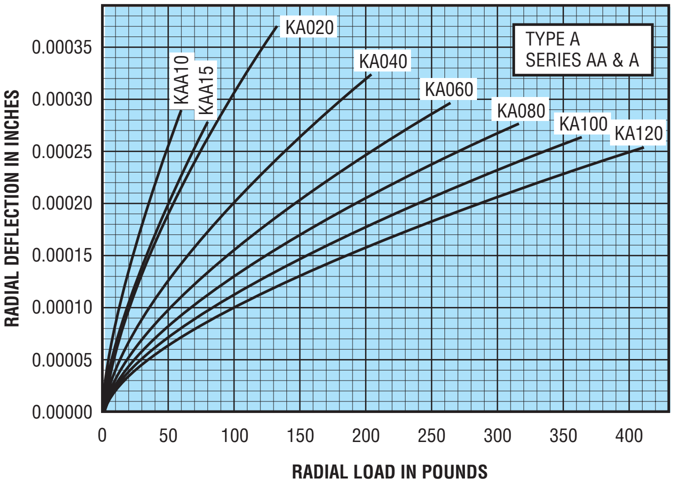


Radial Deflection vs. Radial Load

Type A Angular Contact

For more detailed information, use KAYDON REALI-DESIGN™ software

Figure 4-23



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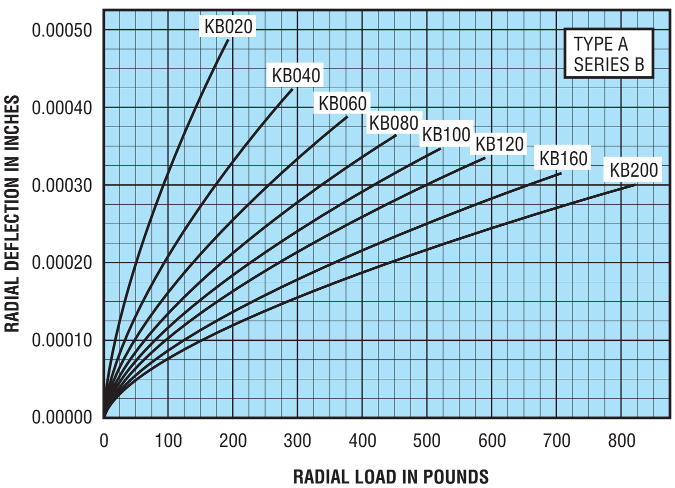

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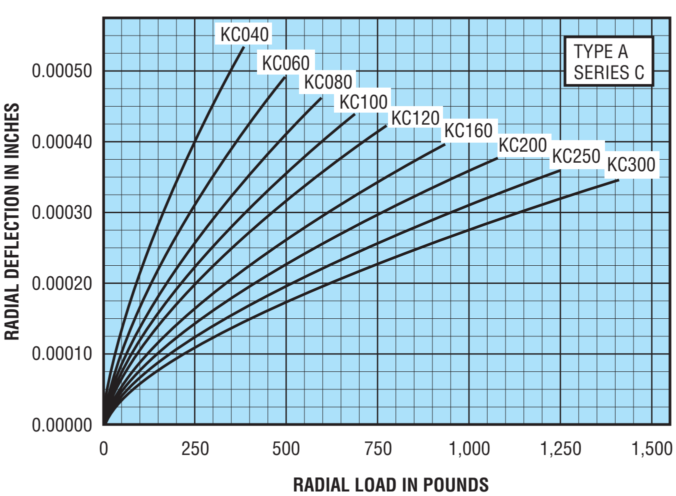

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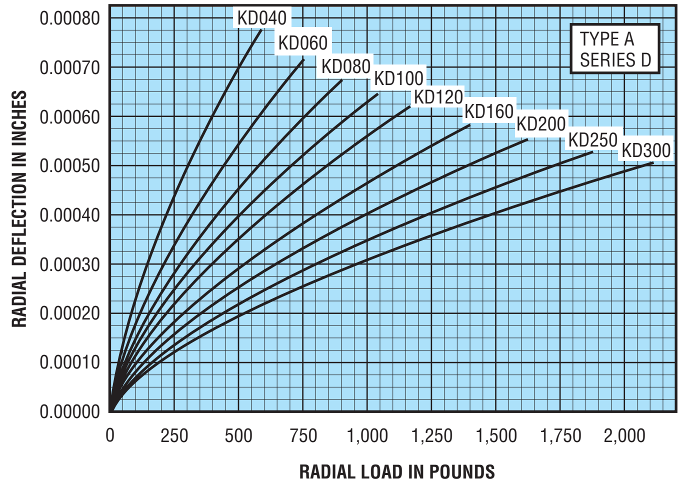

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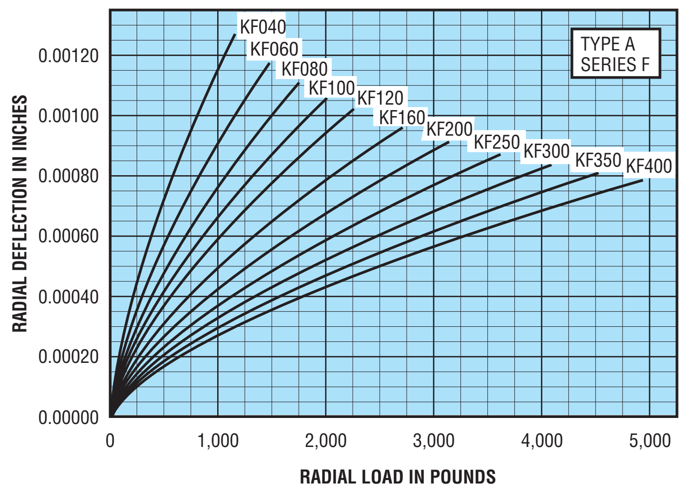

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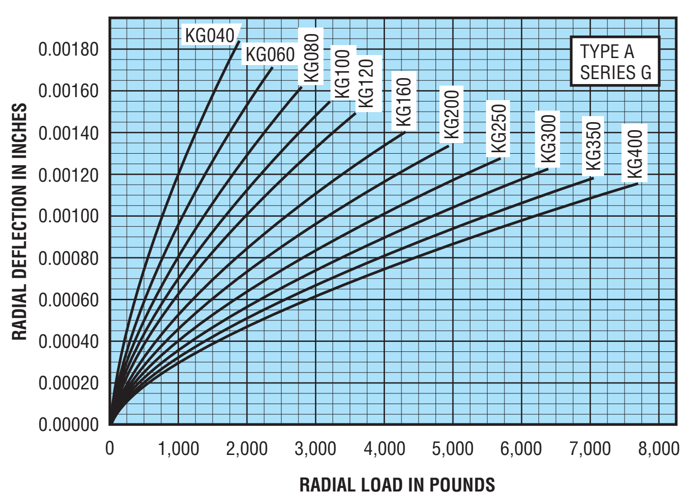


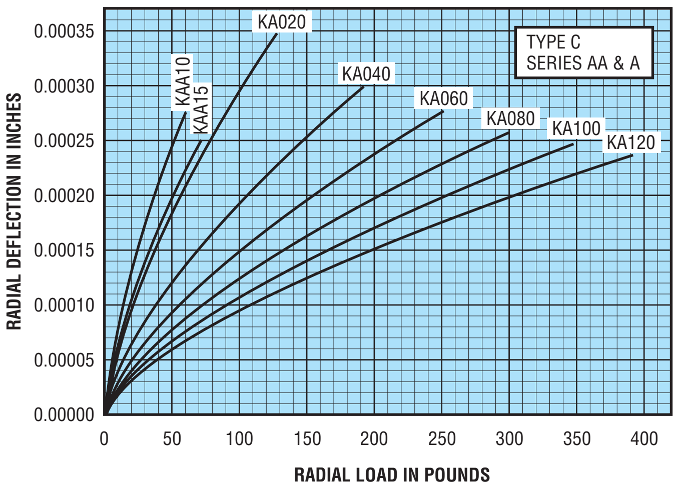
Section 4–Separators, Balls, Performance

Radial Deflection vs. Radial Load

Type C Radial Contact

For more detailed information, use KAYDON REALI-DESIGN™ software

Figure 4-29



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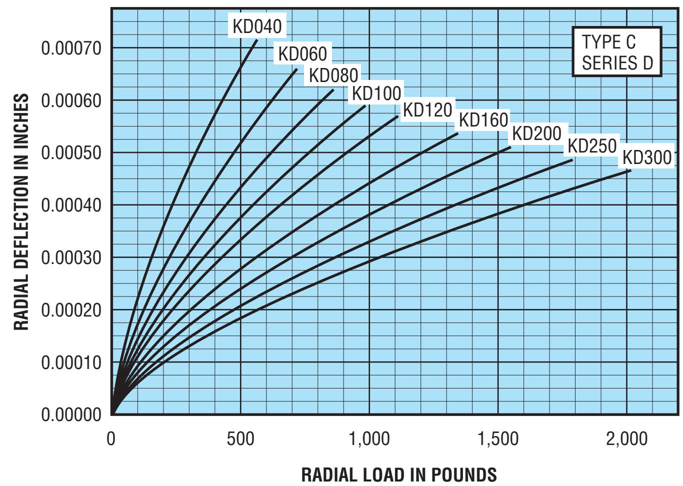

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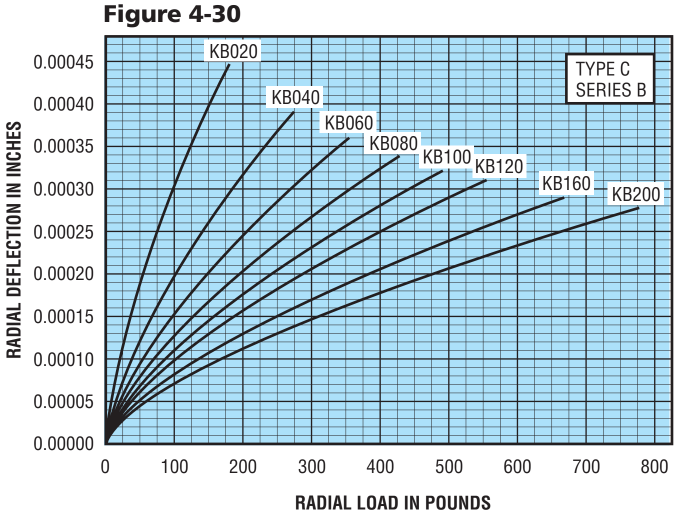

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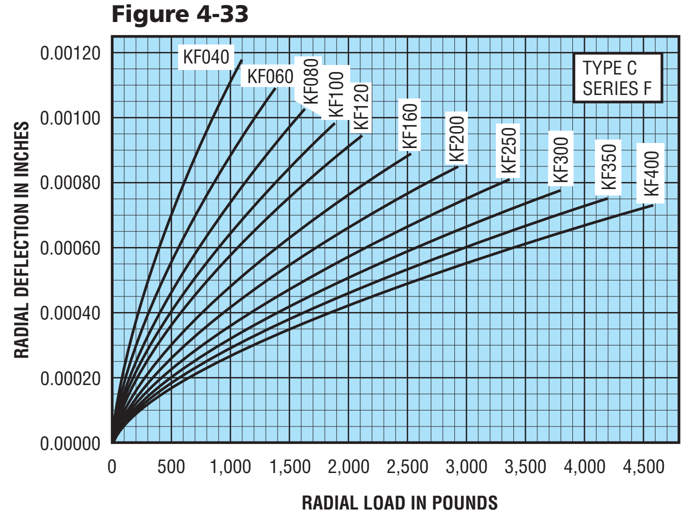

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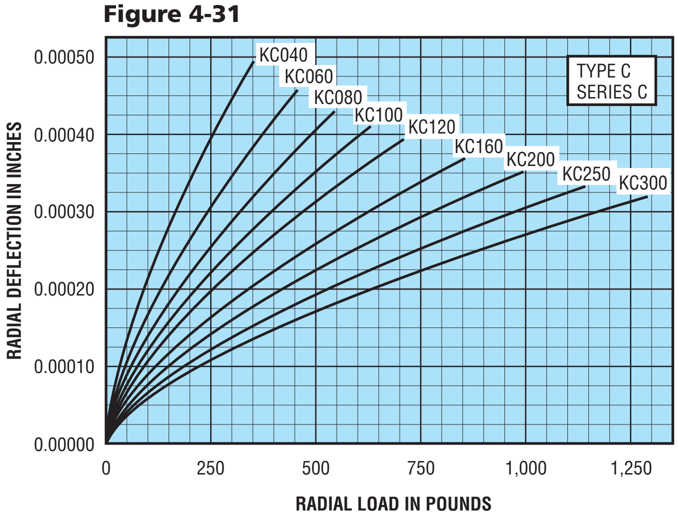

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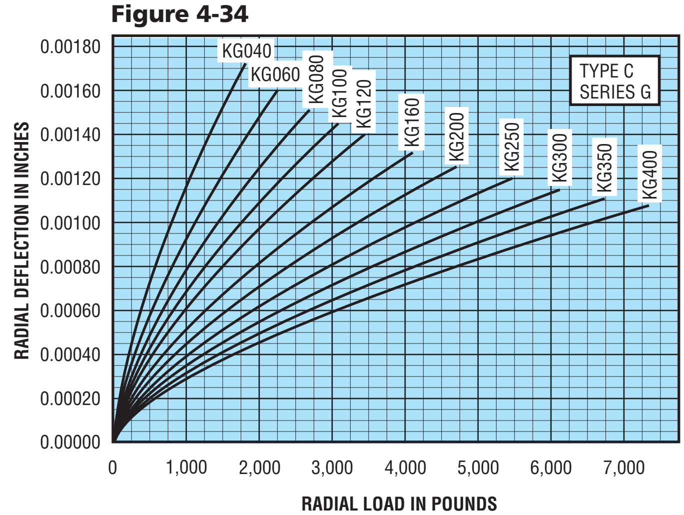
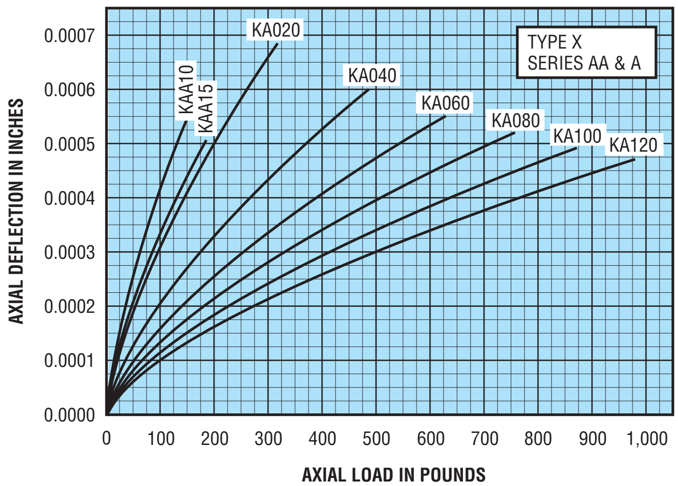


Axial Deflection vs. Axial Load

Type X Four-Point Contact

For more detailed information, use KAYDON REALI-DESIGN™ software

Figure 4-35



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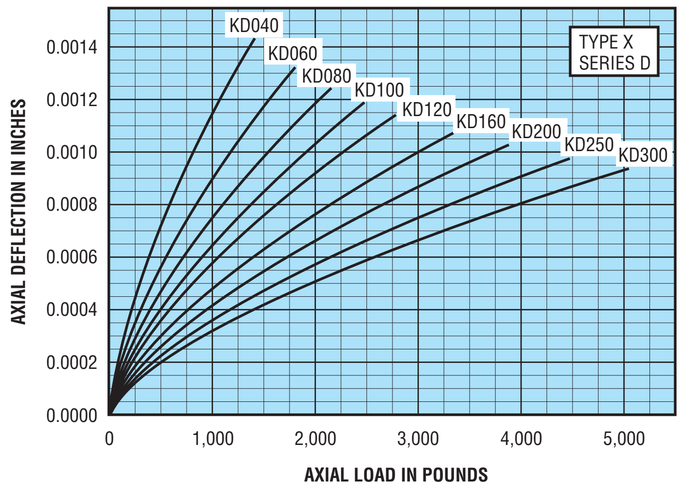

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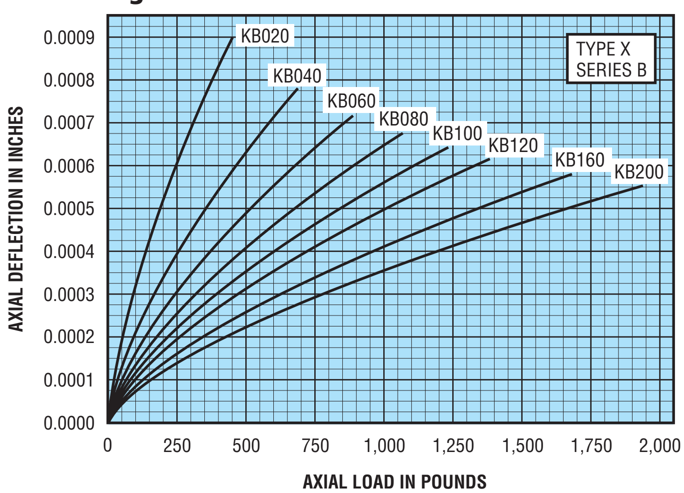

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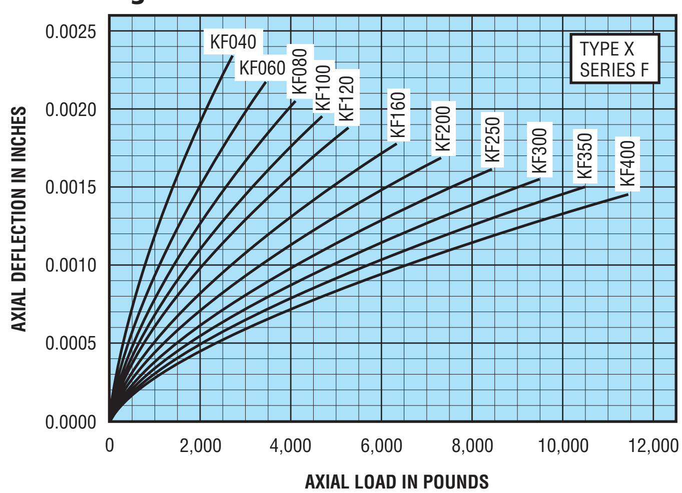

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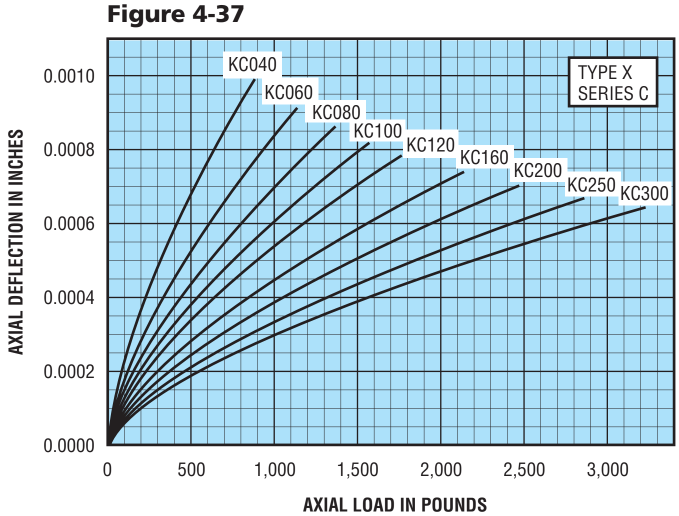

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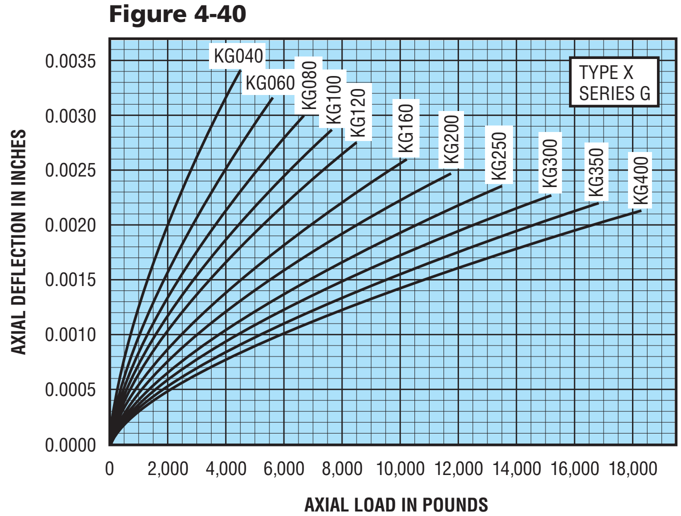
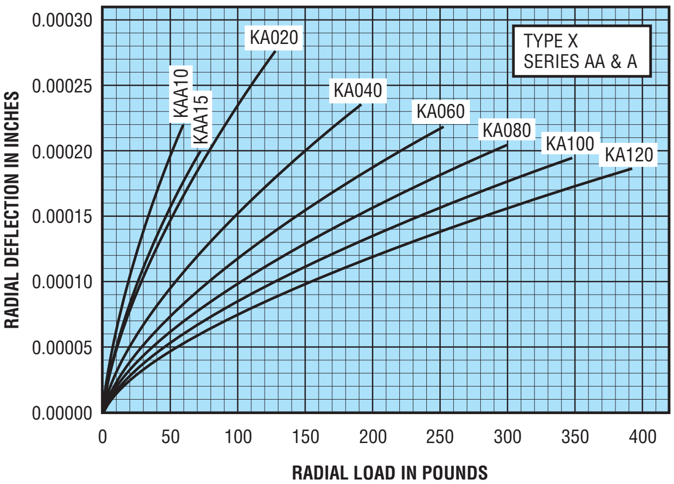


Radial Deflection vs. Radial Load

Type X Four-Point Contact

For more detailed information, use KAYDON REALI-DESIGN™ software

Figure 4-41



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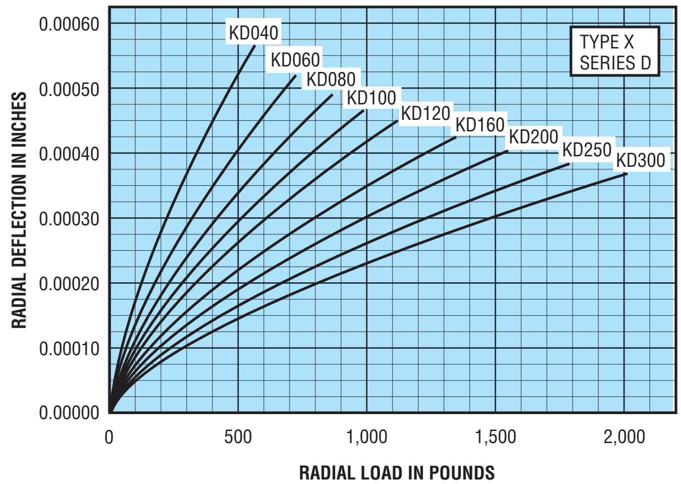

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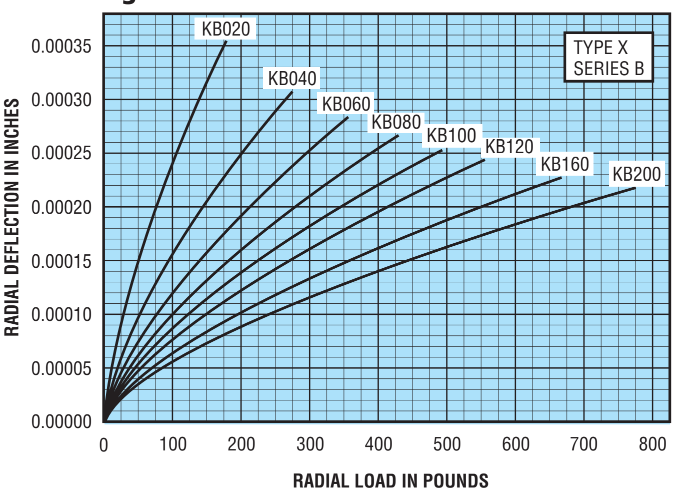

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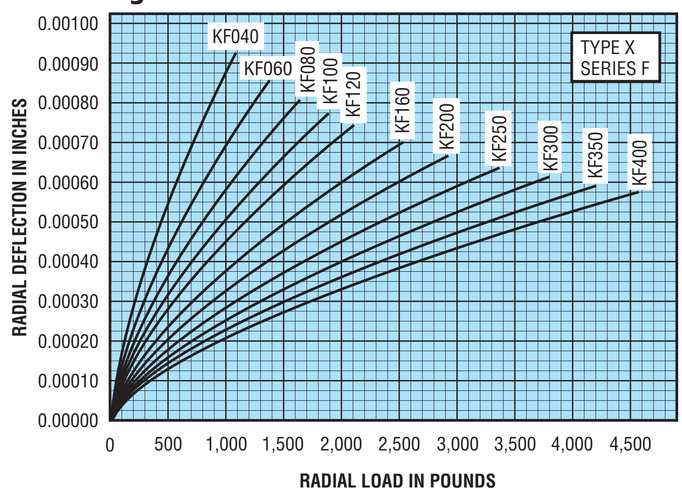

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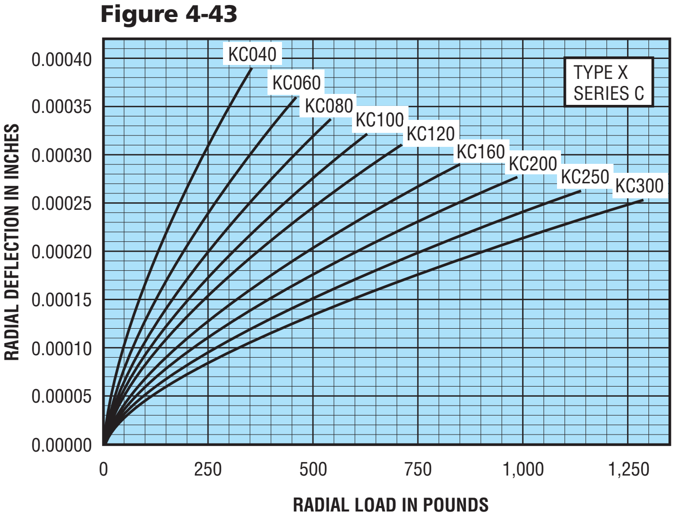

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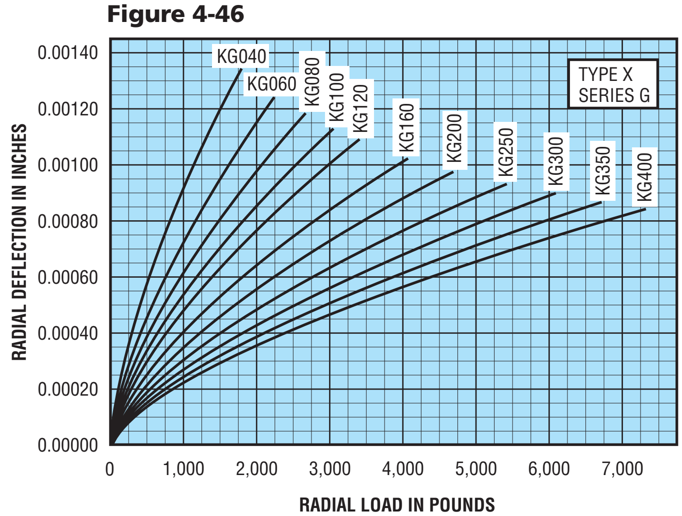
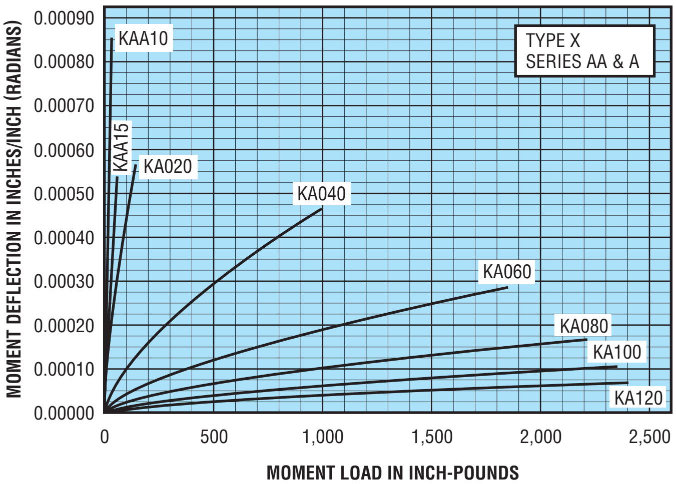


Moment Deflection vs. Moment Load

Type X Four-Point Contact

For more detailed information, use KAYDON REALI-DESIGN™ software

Figure 4-47



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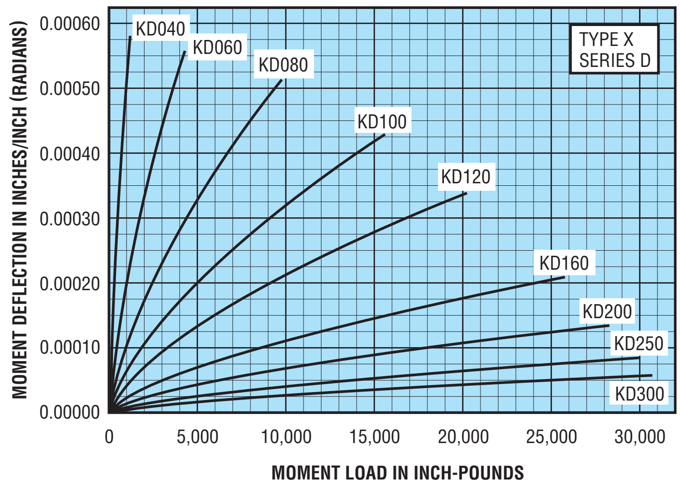

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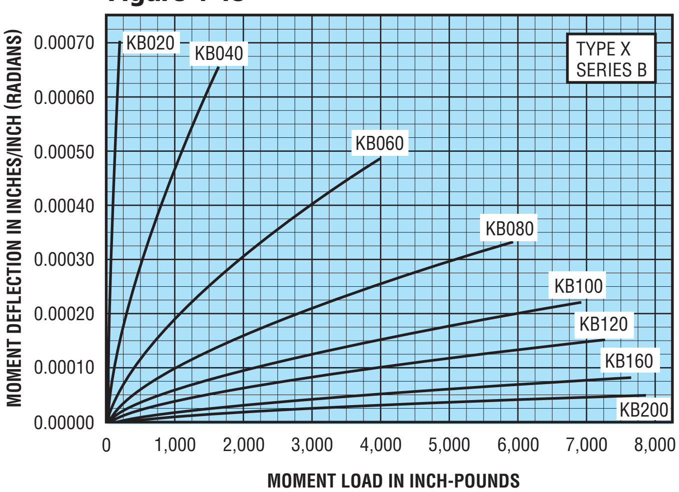

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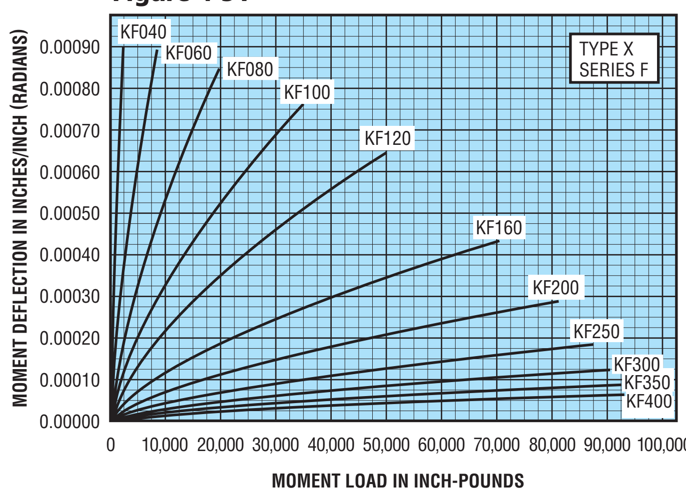

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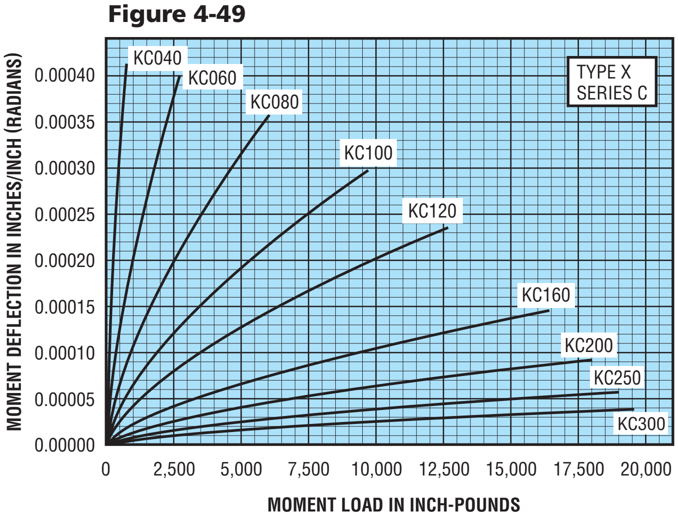

Figure 4-52