On lock down

Retaining rings fasten components on shafts and in housing bores. They are secured on grooves to create a shoulder that holds assemblies in place.

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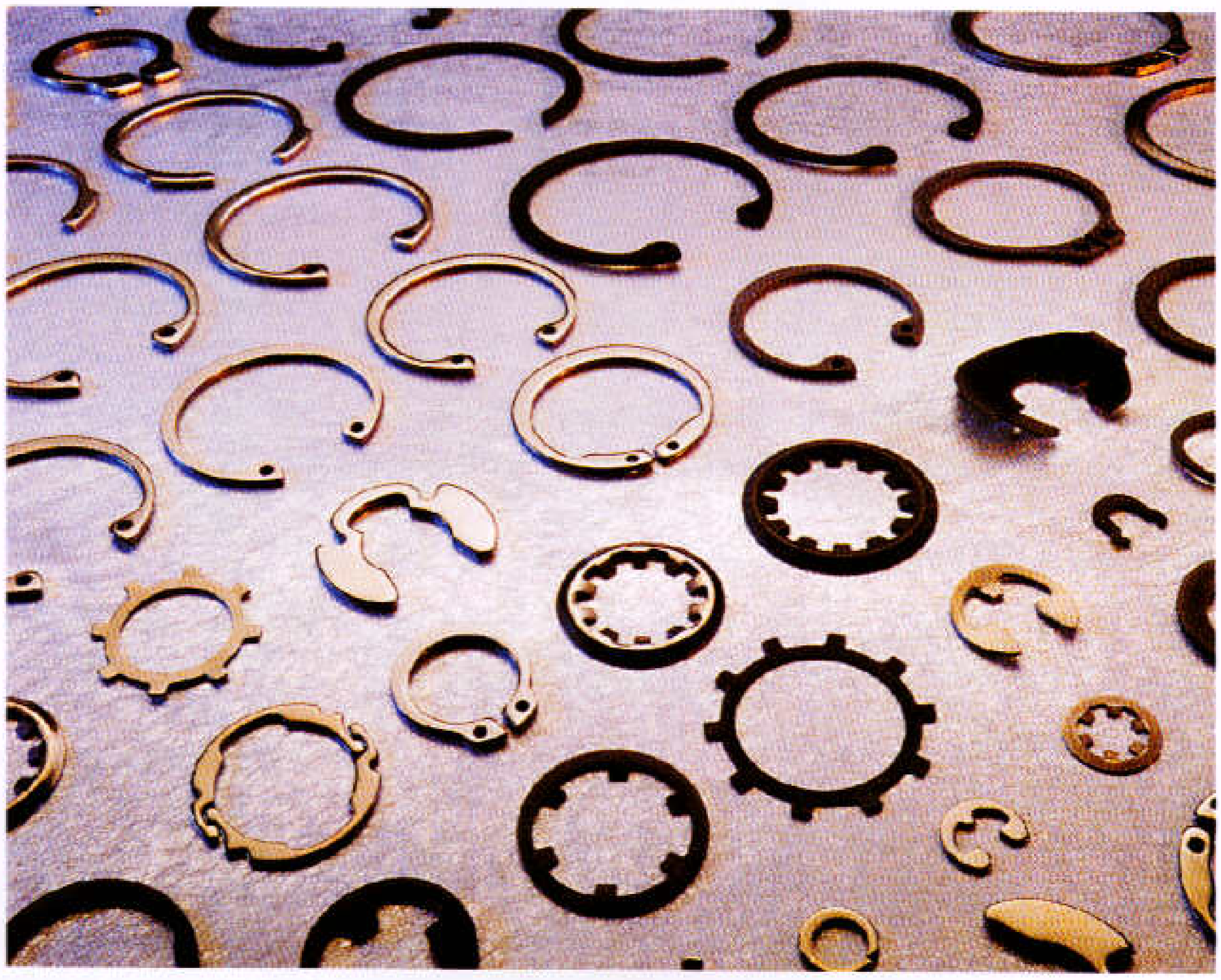
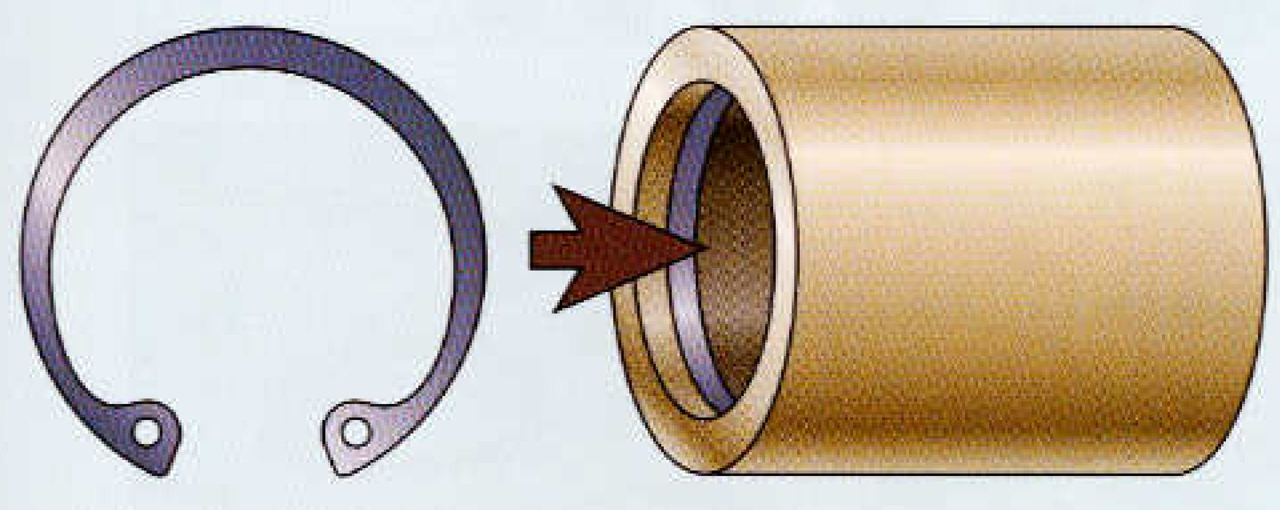


With nothing to hold them in place, shafts and other components can easily walk out of fixtures during operation. Like traditional screws, bolts, and cotter pins, retaining rings prevent moving components from vibrating loose — but they're more efficient and cost-effective. The rings function with a minimum amount of surface preparation; an indentation machined into the housing or shaft is all a ring needs to stay in place. Once snapped into this groove, the retaining ring makes a shoulder that holds components stationary, even keeping assemblies snug if needed. Two major types exist for different applications. Internal-type housing rings keep assemblies in housing bores together, while external-type shaft rings hold components on shafts. Beyond that, retaining rings are further classified by how they're installed.

Axial retaining rings slide down the centerline of an axis onto a groove. They can be placed in internal housings or externally on shafts. Their identifying feature is their pair of lugs with holes, which help machinery grab and open (or squeeze) the rings for assembly. Axial rings make almost complete circular contact with the groove, enabling them to withstand significant thrust loadings. And though they're small pieces, these finishing parts can be made to world standards — English, DIN metric, ANSI metric, and JIS. Again, they are installed in an axial (horizontal) direction in a housing bore or on a shaft.

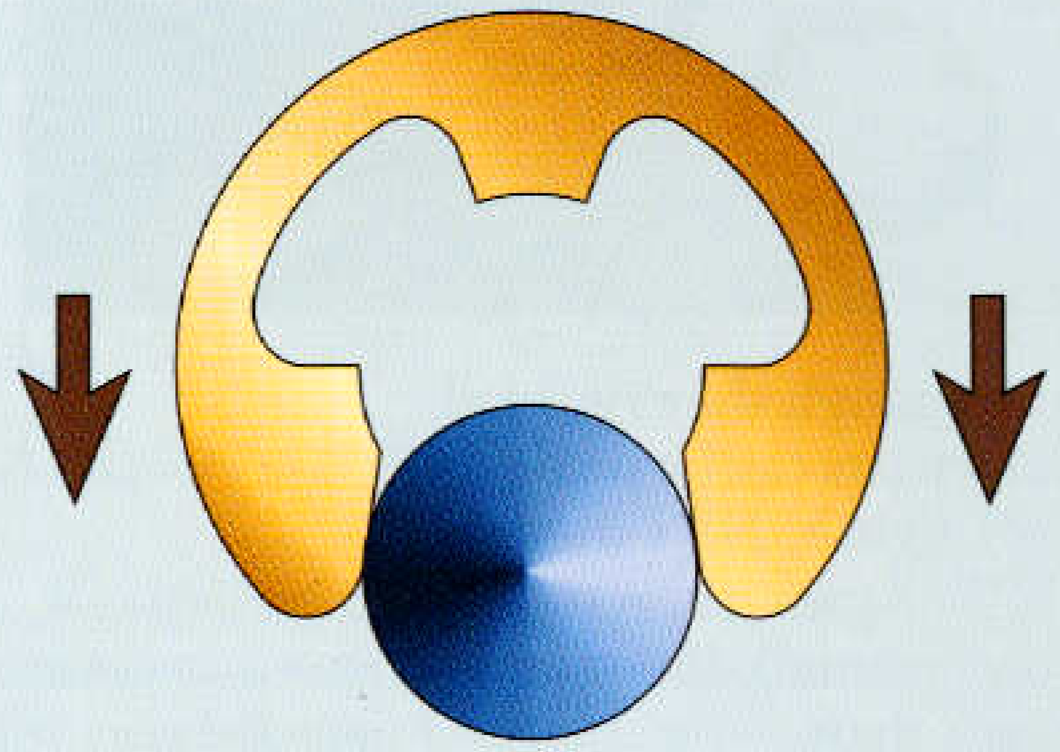
The other ring type is a **radial** ring. Instead of being spread or squeezed for assembly, radial retaining rings are briefly stretched and "snapped" into place, applied vertically toward the center of a shaft. For this reason, all rotor clip radial retaining rings are external — made to be placed on solid shafts. They don't have lug holes or lugs and don't extend as far around the circumference of the groove as their axial counterparts, so they accommodate less force. For this reason, external shaft retaining rings are designed for lower thrust applications. Even so, radial rings are made of less material to cost less, and are available in even the smallest sizes. In addition, the same size ring can be installed on many different shaft sizes simply by machining a deeper or shallower groove. Finally, radial rings can be installed on stepped shafts in place of axial rings, which might be overstressed during installation.

Internal axial ring



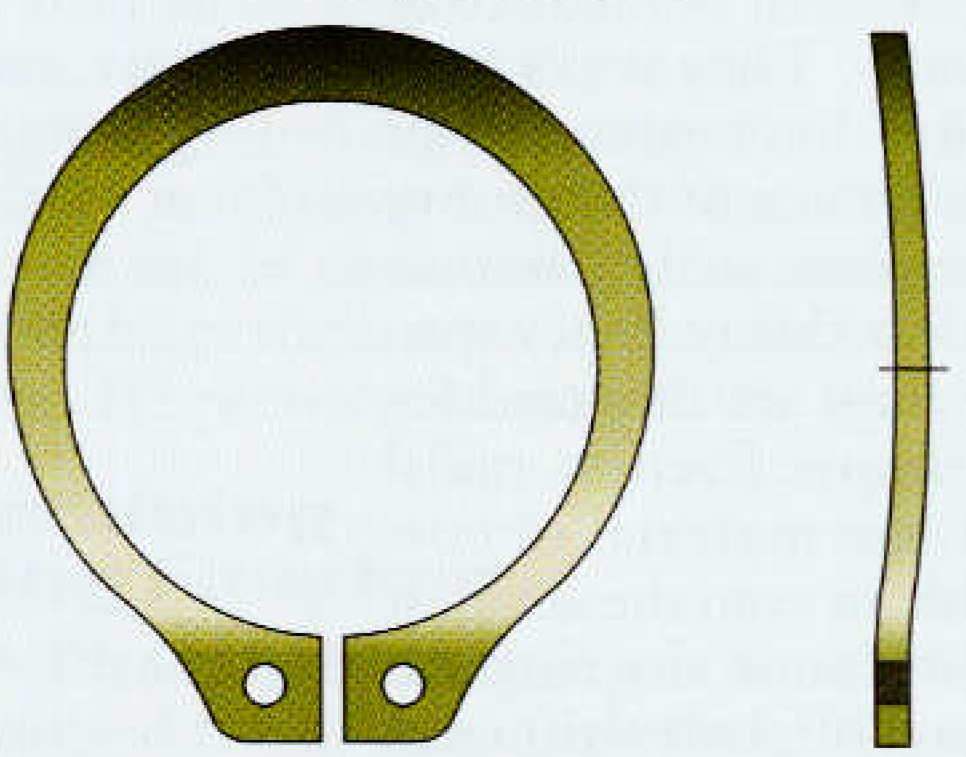
Axial retaining rings slide down the centerline of an axis onto a groove. Unlike radial rings, they can be placed into housings.

Radial ring



Radial retaining rings snap into place. Because they don't extend completely around the groove circumference, they accommodate less force.

For preload



Bowed rings compensate for accumulated tolerances, bending for tight fits and taking up slack for loose assemblies. The bowed ring shown here is an external axial ring.

Another function: For preload

Parts can never be produced to exact dimensions, so during assembly errors accumulate. This means the final product might be significantly off its exact target dimensions. For example, the tolerances of a generally undersized component series might sum to overall system looseness. In this case, a standard retaining ring can't take up system slack. On the other hand, accumulated tolerances (if most components are oversized, or if one component is very oversized) might also equate to an overly snug assembly. In this case, a standard ring might be crowded out of its groove. To deal with these two scenarios, a retaining ring must be able to expand or retract in thickness to accommodate assemblies taking up more or less space. Acting as a spring or preload to reduce chatter or vibration on parts, either a bowed or a beveled retaining ring is needed. These are available for both internal and external applications.

Sizing retaining rings

The distance from the groove to the end of a shaft or housing is known as edge margin. Edge margin is a calculated distance based on the relationship between the edge margin y and the groove depth d. When $^{y}/_{d} \geq 3$, the groove will withstand the maximum thrust load as indicated in charts for specific retaining ring types and sizes. For example, assume an external retaining ring is placed on a shaft with a diameter of 0.5 in. General guidelines suggest that the edge margin should be at least 0.048 in., while the groove depth should be at least 0.016 in. In that case,

$$\frac{y}{d} \geq 3 \; or \; \frac{0.048 \text{ in.}}{0.016 \text{ in.}} = 3$$

There is sufficient edge margin for the groove to withstand the maximum thrust load of 550 lb recommended in charts.

If an application requires an edge margin less than the recommended specifications, it is necessary to calculate the thrust load P_g capacity of the groove to determine if the reduced margin is capable of handling the anticipated load.

$$Pg = \frac{G_f \cdot D_s \cdot d \cdot \pi \cdot \sigma_y}{K_1 \cdot F_s}$$

Where σ_y = Yield strength of groove material
and G_f = Correction factor, ranging from 0.25 to 2 depending on ring duty: thickness and material.

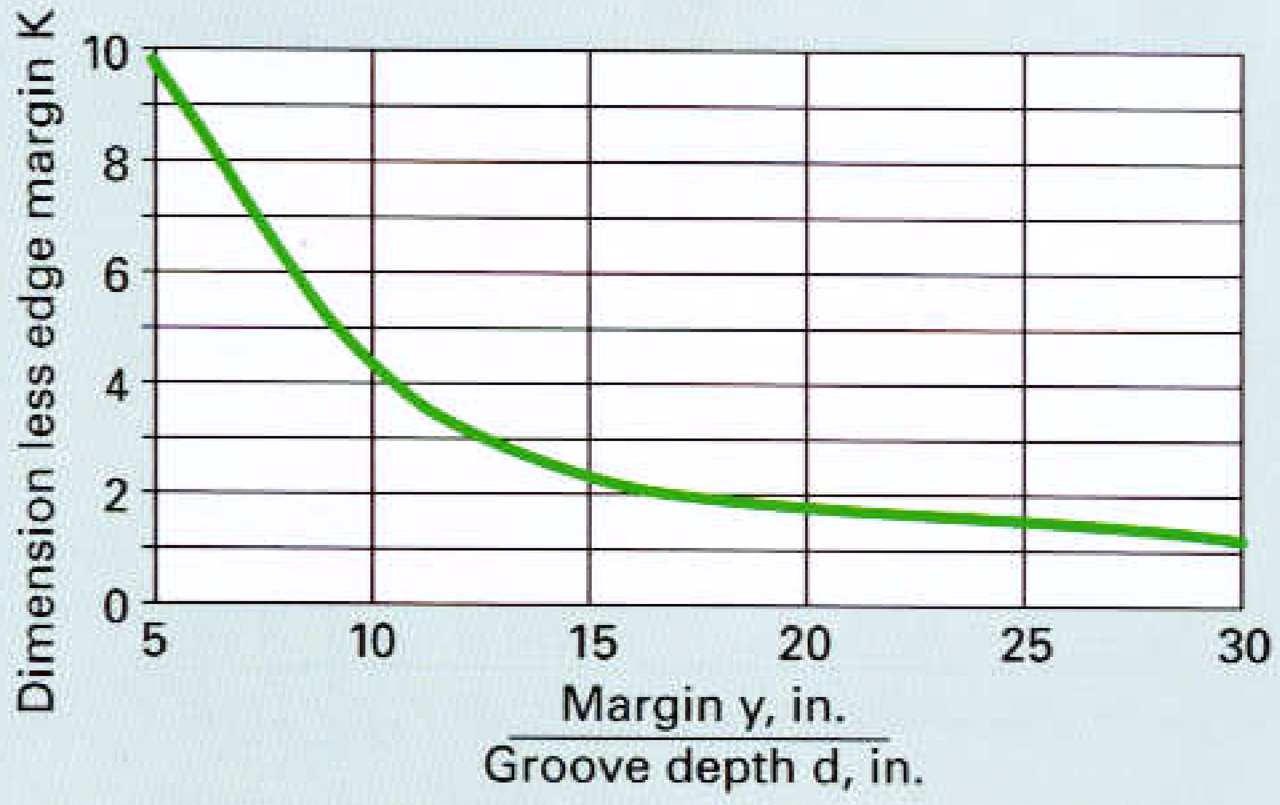
To continue with our example, assume the edge margin will only be half the listed, recommended value. Then the thrust load capacity becomes

$$Pg = \frac{1 \cdot 0.5 \cdot 0.016 \cdot \pi \cdot 45{,}000}{2.20 \cdot 2}$$

$$= \frac{1130.4}{4.40}$$

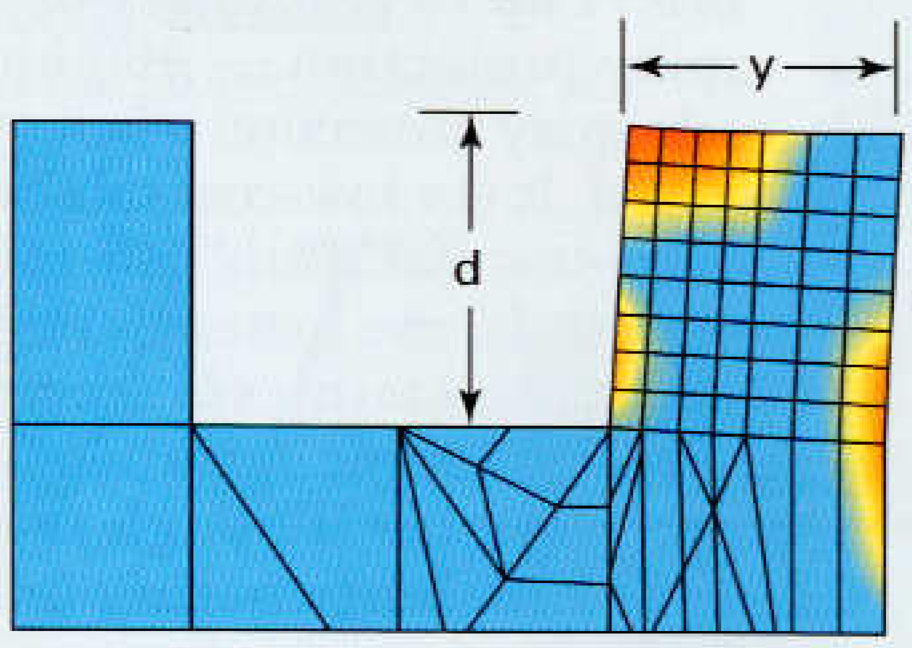
$$= 256.9 \text{ lb}$$

Edge margin



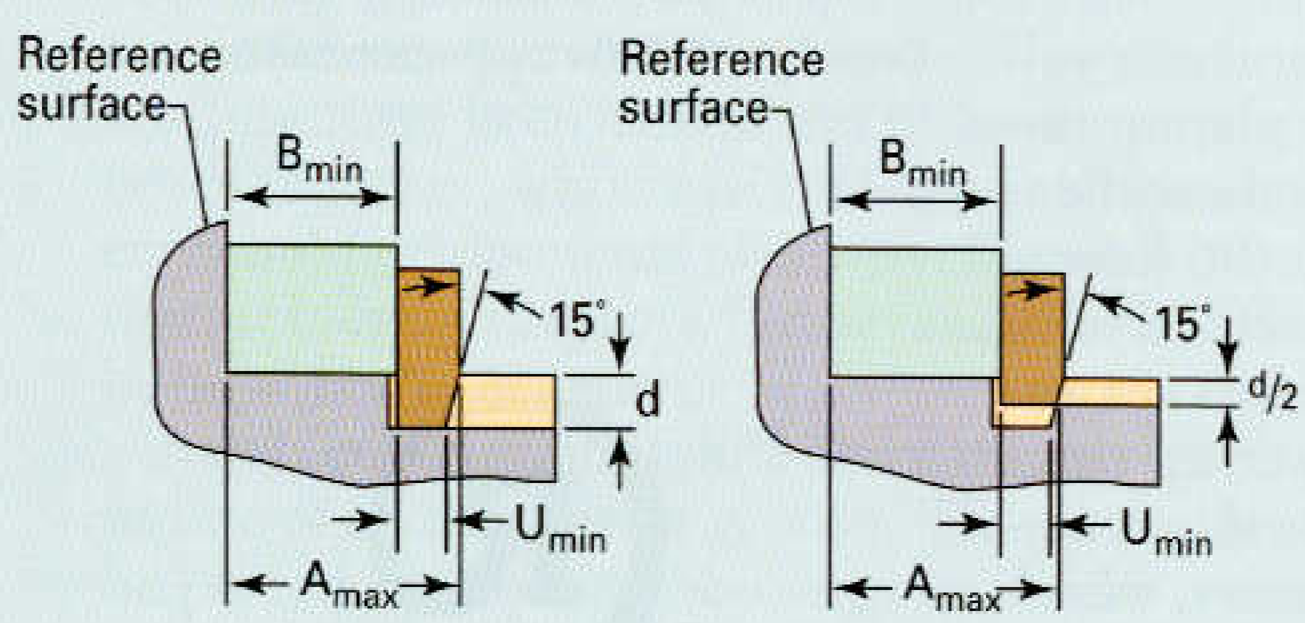
The distance from the groove to the end of a shaft or housing is the edge margin. It's expressed as a ratio to groove depth.

Impending failure



Finite element analysis of an application with insufficient edge margin shows that a high-stress region forms over the entire groove wall to the end of the shaft or housing. Under these conditions the groove distorts, and the ring can fail.

Groove geometry



Beveled rings are not appropriate for all assemblies. Here is (left) the maximum insertion and (right) minimum insertion of a beveled retaining ring.

Again, this returns the maximum thrust load for reduced edge margin.

Beveled rings

When retaining rings are beveled, they can function in a range of groove seating depths, from the bottom of the groove — maximum insertion — to a recommended position halfway up the groove depth — minimum insertion.

The complementary groove and ring bevel allow the ring to function like a wedge when it makes contact with the retained part. The ring exerts an axial force when it makes contact with a retained part, taking up play and effectively reducing the clearance between the parts to zero. If the sum of the assembly tolerances consisting of the retained part width B, the groove location A, and the ring beveled edge U exceed the end play take-up capacity of the ring, two conditions could occur. One is that the ring seats less than halfway down the groove depth, compromising the thrust load capacity of the assembly. The other negative result is if the ring seats at the groove bottom, play will be present.

The outer groove wall with the beveled edge locates the groove. The distance from a fixed shoulder to the outer beveled groove wall is A. The machining tolerance associated with locating the groove is ΔA. The width of the retained part or parts is B. U is the beveled thickness at the base of the bevel.

The feasibility of a beveled ring should be evaluated first. The built-up tolerances of the system must be less than or equal to the take-up capacity of the ring. For example, say a bearing must be retained on a 3-in. shaft. Assume the bearing width is 1.000/0.995. Before the location can be determined, it's necessary to determine the acceptable machining tolerance ΔA. (For this example, let's assume that value is +0.003/-0.000.) Then the sum of tolerances is

$$\Delta B = B_{max} - B_{min} = 0.005$$
$$\Delta A = A_{max} - A_{min} = 0.003$$
$$\Delta U = U_{max} - U_{min} = 0.004$$

$$\Sigma\Delta = 0.012$$

The sum of tolerances is less than the take-up capacity of the ring (0.0135), confirming that the ring will seat within the acceptable limits in all assemblies.

To determine the distance from the defined shoulder — the plane of reference — to the top of the far groove wall A

$$A_{min} \geq B_{max} + U_{max} + \frac{d}{2\tan 15°}$$

$$A_{max} \leq B_{min} + U_{min} + d\tan 15°$$

Using the values

Ring dimensions

SHAFT DIAMETER, IN.	0.125	0.250	0.500	1.000	1.250	2.000	2.500	3.500
DEPTH *D*, IN.	0.004	0.010	0.016	0.030	0.037	0.057	0.070	0.092
GROOVE SAFETY FACTOR OF TWO	35	175	550	2,100	3,250	8,050	12,350	22,800
EDGE MARGIN *Y*, IN.	0.012	0.030	0.048	0.090	0.111	0.171	0.210	0.276

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from the above example, minimum groove engagement A_{min} and maximum groove engagement A_{max} can be computed:

$$A_{\min} \geq 1.000 + 0.073 + \frac{0.102}{2 \cdot \tan 15^\circ}$$

$$A_{\min} \geq 1.087$$

$$A_{\max} \leq 0.995 + 0.069 + 0.102 \cdot \tan 15^\circ$$

$$A_{\max} \leq 1.091$$

$$A_{nom} = \frac{A_{\max} + A_{\min}}{2} - \frac{A_{\max} - A_{\min}}{2}$$

$$A \Rightarrow 1.089 - 0.002$$

Reviewing our stack-up of tolerances, we assumed 0.003 in. for machining. Our calculated groove location allows for more leniency (0.004 in.) in the tolerance. Checking the $\Sigma\Delta$ again, we find that the assembly is still within the 0.0135 limit for end-play take-up.

From knowing ring dimensions, retained part dimensions, required groove depth, and designated machining surface, the groove can be easily located for assemblies meeting the $\Sigma\Delta \leq {}^{d}/_{2}\tan 15^\circ$ primary requirement.

Retaining Ring Finishes

• **Phosphate coating** is a standard finish recommended over unfinished plain steel, because it offers an extended shelf-life protection against rusting. Phosphate and oil finishes provide eight-hour salt spray protection; heavy phosphate and oil provides 72 salt spray hours and can be used in place of costly stainless-steel material in some applications. Another variation is phosphate with sealer, which is a coating added to the finish to control loose phosphate crystals on the part surface.

Yield strengths

GROOVE MATERIAL	YIELD STRENGTH, PSI
Cold-drawn steel	45,000
Steel, SAE 1045, Rc 42	185,000
Steel, SAE 1045 Rc 48	220,000
Aluminum	48,000
Naval brass	53,000

The groove on the shaft or housing affects the performance of installed retaining rings; its strength especially determines which rings are most appropriate.

• **Zinc plating** features a yellow dichromate post plating finish. It affords the metal excellent salt spray protection (96 hours) and is particularly effective in applications exposed to seawater. (Some steel retaining rings are even zinc plated using a mechanical plating process, which effectively eliminates hydrogen embrittlement.) With **zinc bright** finishes, most of the dichromate is leeched out of this process, leaving a 'bright' silver finish on parts. While this finish offers some corrosion protection (to 48 hours of salt spray) it's most widely used when aesthetics are a factor. **Zinc dicromate laquer** is an improved finish that offers up to 240 hours of salt spray protection — 480 hours salt-spray protection when optimized. It is a low-cost substitute for costly non-corrosive materials such as stainless steel in some applications.

• Though **trivalent coating** is still undergoing testing, it does meet global requirements for hexavalent-free coatings. In fact, new standards are being written for its use in the automotive industry on retaining rings. **MSD**