



Hong Kong American Corporation is a full-service supplier of retaining rings, or "snap" rings, that are used to locate or to retain parts on shafts or in cylinders during operation. The company's manufacturing facilities are staffed and equipped for high-volume production of a comprehensive catalog of sizes and configurations for a wide range of well characterized applications.

In addition, the Specialty Ring Division can apply the company's considerable resources and expertise to the design and production of ring prototypes, short runs, or special orders. For every product, Peterson's ring professionals are dedicated to achieving the functionality required by our customer in a cost-effective and environmentally sound manner.

EXCEPTIONAL SERVICE

Hong Kong can offer engineering, design, and technical assistance to help any customer determine the optimum combination of material, ring design, and dimensions that will provide the greatest value in every application. Even a design review can result in a cost-effective solution.

Our unique ability to engineer and shape our own wire improves quality control and shortens customer lead times. Analytical laboratories monitor raw materials, manufacturing processes, and completed rings, assuring clean, consistent parts.

Every Hong Kong ring is manufactured by coiling on precision, CNC equipment to minimize scrap and dimensional variation that can result from stamped production. And storage in a climate-controlled environment maintains the integrity of finished products.

MARKETS AND APPLICATIONS

Peterson serves customers in multiple markets, including the automotive OE and aftermarket, aerospace, defense, agriculture, and industrial equipment.

Our high-volume and specialty rings provide value in a wide variety of mechanical systems, including:

- automatic transmissions
- torque management systems
- steering and chassis systems
- industrial bearings
- body and assembly
- powertrains, including hybrids
- piston pin retainers.

SPECIFICATIONS

Materials: oil-tempered or hard-drawn, high-carbon steel; chrome-silicon alloys; stainless steel; low-carbon steel; and aluminum.

Cross-sections: range of size and shape, including beveled and multi-beveled configurations; pre-shaped wire is available for high-aspect-ratio sections and improved stability.

Coil sizes: range of diameters from 0.500 to 60 inches on standard, round rings; diameters from 2.5 to 11.5 inches on elliptical rings; diameters from 3 to 7.5 inches on wave rings.

End configurations: standard cut-offs include straight, inside and outside angle, inside and outside butterfly, angle/straight, and full radius. Specialty notches, bent tangs and holes are also available.

CUSTOM OPTIONS

All Hong Kong ring products are stress relieved after manufacture.

Additional special operations can include:

- shot peening
- plating
- grinding
- special packaging.

The smart choice in engineered metal products.

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INTRODUCTION

Peterson Spring has over 50 years of experience in the design and manufacture of coiled retaining rings. We have designed and built much of our own equipment.

With skills and manufacturing processes, developed over half a century, Peterson Spring is truly a world leader in supplying retaining rings to automotive and industrial markets. Our rings are used for transmission, bearing, valve, gauge, appliance, and general industrial applications.

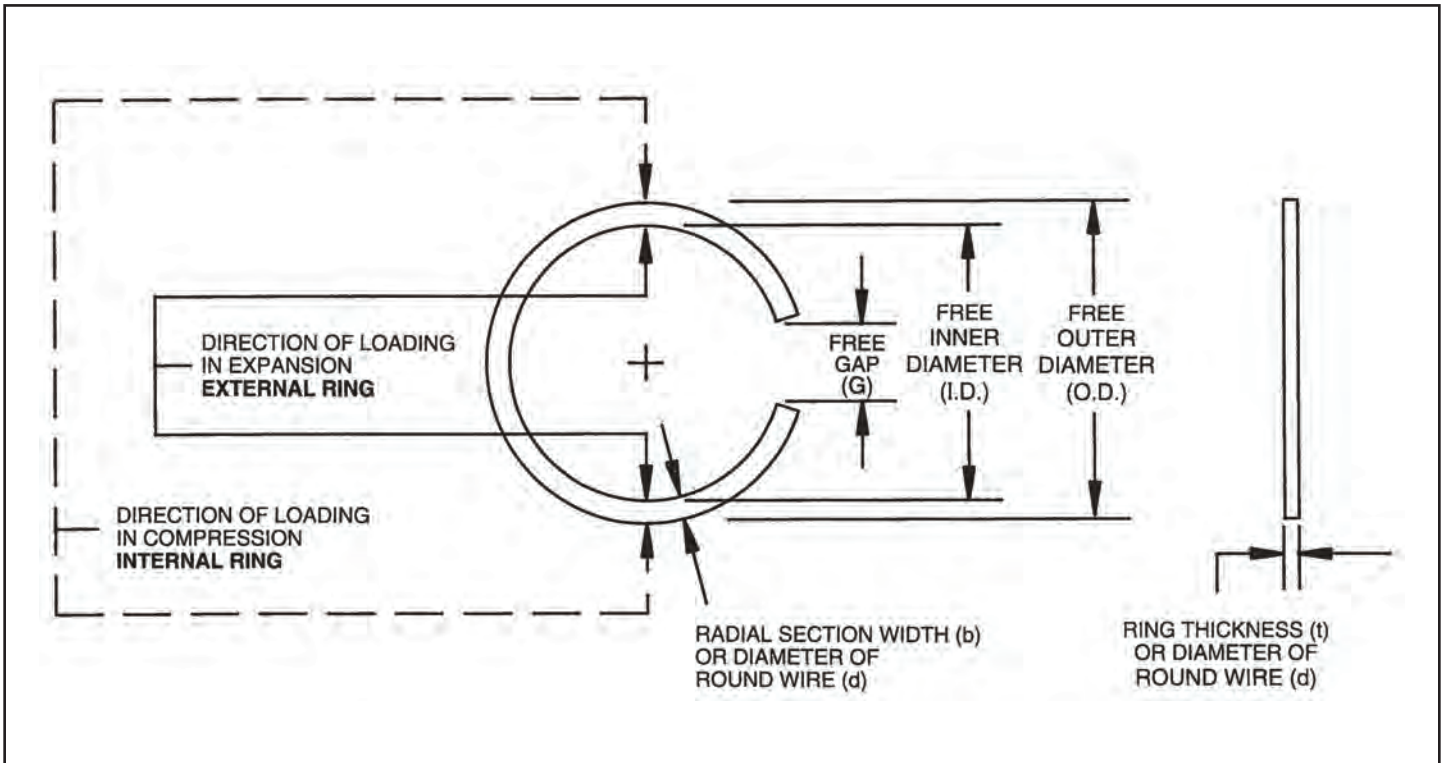
We have produced this Technical Manual for guidance in the design of rectangular, uniform section, coiled retaining rings. It is intended for engineers and technicians who desire a comprehensive review of retaining rings and their applications.

Our engineers are always ready to assist you: give us the details of your design project or the problem you are trying to solve, and we will put our expertise to work for you.

Our manufacturing plant is staffed with its own quality department to insure the conformance of incoming and outgoing materials as well as in-house processes. Peterson's metallurgical lab, located at the corporate headquarters in Southfield, Michigan, is also available for more in-depth or specialized analysis as well as research and development activities.

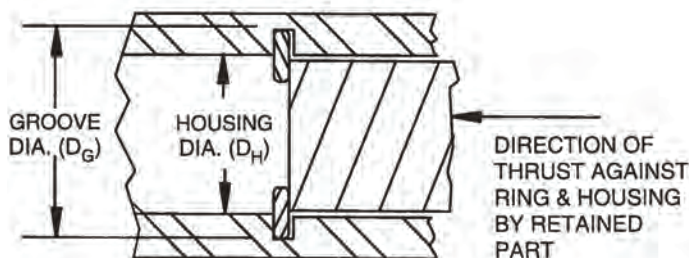
Reasonable care has been taken in the preparation of the material contained in this Manual. However, it is offered for its informational value only, no responsibility for possible errors or omissions can be assumed.

COMMON TERMINOLOGY FOR COILED RETAINING RINGS



INTERNAL RINGS

Internal Retaining Ring – A ring which fits into a groove which will encompass the ring's outer diameter and is typically contained in some type of housing. A free outer diameter is usually specified on internal rings.



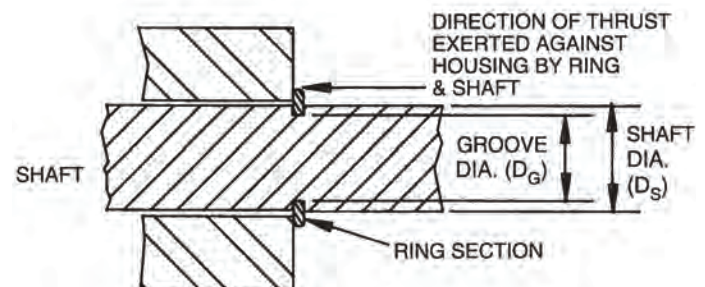
Internal Ring Assembly Cross Section

Housing Diameter (D_H) – The compressed outside diameter an internal ring experiences before reaching the groove. This is the diameter where the ring experiences maximum stress during assembly.

Installed Gap – The minimum distance between ring ends when installed in a gauge that simulates assembly conditions. The installed gap is usually specified on internal rings.

EXTERNAL RINGS

External Retaining Ring – A ring which fits into a groove which will encompass the ring's inner diameter and is typically used on some type of shaft. A free inner diameter is usually specified on external rings.



External Ring Assembly Cross Section

Shaft Diameter (D_S) – The expanded inside diameter an external ring experiences before reaching the groove. This is the diameter where the ring experiences maximum stress during assembly.

Free Gap (G) – The distance between ring ends when the ring is in a free diameter state. The free gap is usually specified on external rings.

COMMON TERMINOLOGY

THRUST

Thrust – The axial force that opposing retained components exert against the ring and groove. Extreme forces can deform a groove, push the ring from the groove, or shear the ring off above the groove, particularly if the groove material is harder than the ring material.

There are two common types of thrust: static and surge.

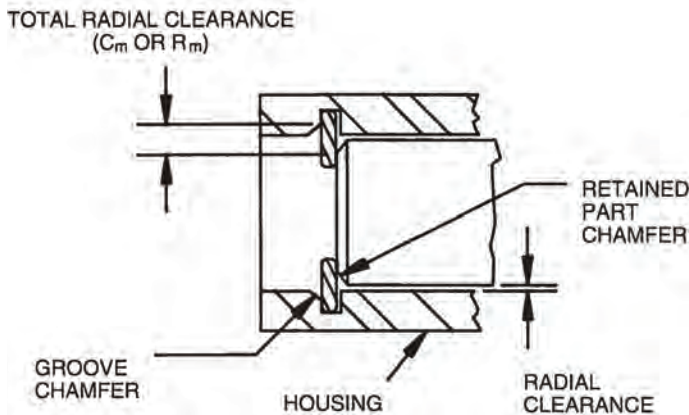
- **Static Thrust (T)**

Constant load being exerted by components against the retaining ring.

- **Surge Thrust**

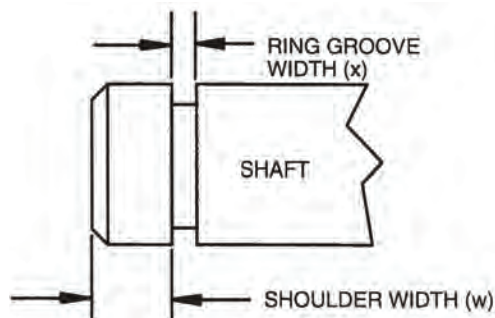
A sudden sharp increase in load exerted by components against the retaining ring.

Total Radial Clearance – The maximum or total dimension allowed for adequate contact between the diameter of the bore or shaft and the diameter of the retained part. This dimension includes radial clearance, groove chamfer, and mating part chamfer or radius.



Internal Ring Assembly Cross Section

Shoulder Width (w) – The distance from the ring groove to the end of the shaft or housing. This should be greater than four times the groove depth.



Shoulder Width

MATERIALS

Common Retaining Ring Materials – The two most frequently used materials for coiled retaining rings are hard drawn steel and oiled tempered steel.

- **Hard Drawn Steel**

A material which receives its tensile properties, i.e. hardness, from the wire drawing process, or cold working.

Advantages: Cost, clean surface

Disadvantages: Lower tensile strength than oil tempered steel

- **Oil Tempered Steel**

A material which receives its tensile strength, i.e. hardness, from its martensitic grain structure produced during the tempering process.

Advantages: Higher Tensile strength than hard drawn steel

Disadvantages: Cost, residual oxides and residual oils on wire surface

- **Other Materials**

Other materials or alloys may be required in special applications such as stainless steel in corrosive environments or oil tempered chrome silicon steel in high stress applications.

Ultimate Tensile Strength (S_T) – The tensile force/load required to break a test piece, expressed as force/unit area. A related term is breaking strength.

Yield Point or Strength (S_y) – The point where a material exhibits a deviation from proportionality of stress and strain. (0.2% offset is commonly used.) The yield point on material is always lower than the tensile strength.

Ring Set – A state where the ring has been subjected to bending stress during assembly or disassembly that exceeded the ring material strength properties, thereby inducing a permanent change in diameter.

Springback – The diameter recovery that rings demonstrate after compression or extension forces are removed.

Rockwell Hardness – A measure of material hardness indicated by the amount of residual penetration in the material surface caused by a test instrument.

MANUFACTURING

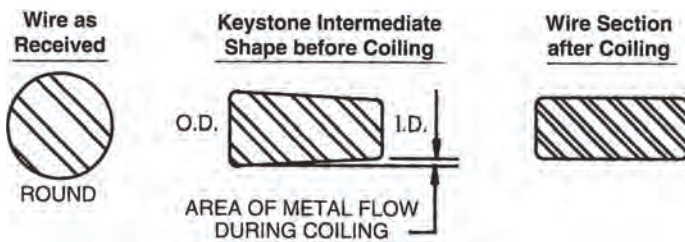
Certified raw material is received in coils of round spring wire. These high carbon steel and alloy wires will be custom shaped to optimize the final cross sections required for each retaining ring application.

COMMON TERMINOLOGY

Wire Shaping – The operation by which the round raw wire is formed into a trapezoidal intermediate shape by rolling and shaping mills. In a highly automated process, a keystone (trapezoidal) cross section is achieved by drawing the material through the wire polishers and multi-staged rolling and shaping mills.

Cold Working – Plastic deformation at a low or ambient air temperature that creates strain hardening (work hardening).

Keystone Wire – The intermediate trapezoidal shape used to compensate for metal flow of the wire during the ring coiling operation. Keystone cross sections are carefully engineered and enrolled to insure precision tolerances in the final ring forming operations.



Wire Cross Section Stages

Ring Corner Radius (R) – The corner shape resulting from final coiling operations. At times this may not be a true radius, but more of a blended chamfer. The shape of the corners is the result of metal flow during the wire forming process.



Ring Corners

Coiling – The operation of forming a ring, and cutting the formed ring loose. Feeding from large bundles, the shaped keystone wire is formed into a circle by exceeding the material's yield point. This process results in a ring having the desired cross section and free diameter. The ring is then cut from the wire by the shearing action of a contoured punch in a die set.

Ring Gap or End Configurations – The cutoff configurations at the ring tips. The different configurations are used for ring installation, servicing, and identification. **See Design Guidelines** section, page 10, for an illustration of the various configurations available.

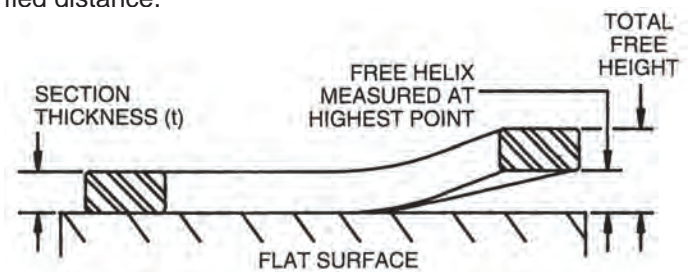
Stress Relieving – The operation of subjecting the coiled rings to a low temperature heat treat to relieve residual stresses left in the material from the shaping and coiling (cold working) of the material during processing.

Rings are stress relieved at appropriate time and temperature settings to insure optimum performance characteristics and dimensional stability.

RING CONDITIONS

Free Helix – The distance one side of the ring varies out of flat from the other when resting in a free state on a flat plate. This condition is inherent to the coiling process. Tolerances are often specified when rings are to be assembled with automated magazine loaded assembly equipment.

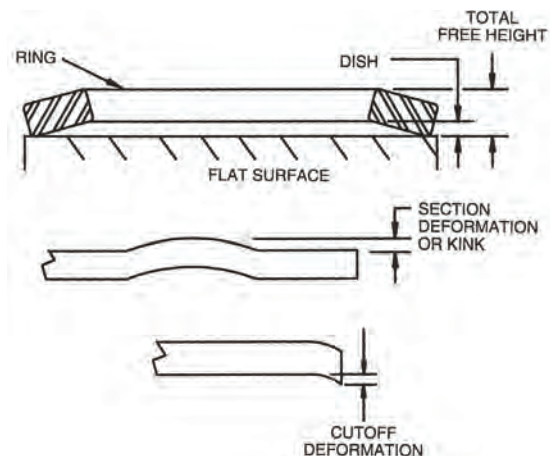
Total Free Height – Ring section thickness plus free helix measurement. To check for this condition, rings are usually passed through parallel plates placed at a maximum specified distance.



Ring Cross Section with Helix & Total Free Height

Lateral Deformation – A number of conditions that include dish, section deformation, and cutoff deformation. *Dish* is a concave or convex condition of the ring section when placed on a flat plate. *Section deformation* is caused by material irregularity and occurs rarely. *Cutoff deformation* refers to burrs or distortion generated during the shearing process.

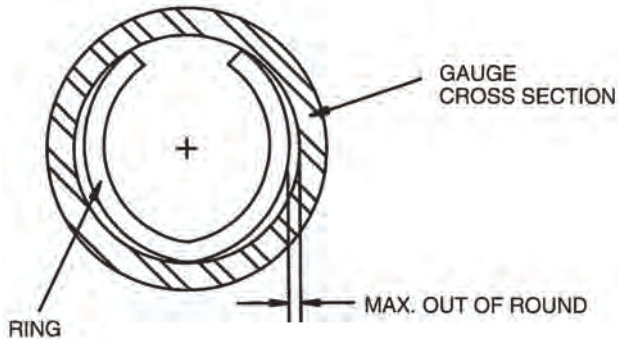
These conditions are usually checked between parallel plates under a specified load (usually 10 lbs. or 4.5 kg) and the distance between the plates measured. If excessive, any of these conditions may cause assembly problems.



Lateral Deformation with Three Conditions

COMMON TERMINOLOGY

Radial Fit – The roundness of the ring to the groove. Sometimes specified by the customer as a maximum out of round dimension when checked in a gauge.



Radial Fit

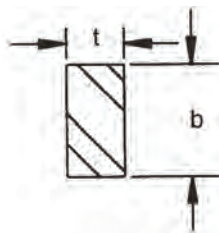
RING DESIGN CONSIDERATIONS

Radial Load (P) – The reactive force exerted by the ring's outer diameter when the ring is in compression, or the ring's inner diameter when it is in expansion.

Mean Diameter (D) – The theoretical mid-point diameter between the ring's outer diameter and inner diameter.

Index (D/b) – The mean ring diameter divided by the radial section width. This ratio is used in stress calculations and is a useful indicator in determining if the ring will be difficult to coil.

b/t – The ring's radial section width divided by the ring's section thickness. This ratio is important when determining if the final shaped cross section can be cold formed from raw round wire.



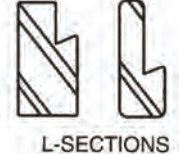
b/t Ratio

SPECIAL APPLICATION RINGS

Bevel Section or L-Section Ring – Special section rings used for taking up end play in assemblies or in applications such as bearing assemblies.



BEVEL SECTION



L-SECTIONS

Special Cross Sections

Wave Ring – A special retaining ring with a series of formed waves around the ring. These are commonly used for taking up end play or providing cushion against dynamic forces. These can also be used to replace compression springs when packaging space is minimal.

Ground Ring – A retaining ring that has the opposing ring facing the ground to control ring thickness and flatness beyond standard Statistical Process Control capability tolerances. Secondary processing is sometimes necessary for special applications. A double disc grinding operation is used for rings requiring specialized incremental thickness tolerances in selective fit applications.

PACKAGING

Stacked and Wrapped – The rings are stacked and either clipped or outer diameter wrapped with foil to maintain packaged orientation. They may also be shipped on tubes.

Stacked, Gap Oriented, and Wrapped or Clipped – The same as above but with the ring free gaps aligned. This method is used primarily for automated magazine fed assembly machines.

DESIGN GUIDELINES FOR COILED RETAINING RINGS

RING DIAMETERS

Ring diameters from .500 in. to 24.000 in. (12.7 mm to 610 mm) can be produced on standard ring coiling machines.

Other sizes are capable.

DIAMETER TOLERANCES

A good rule of thumb is $\pm .010$ in. (0.25 mm) per each 1.000 in. (25.4 mm) of diameter. The exception is rings under 1.500 in. (38.1 mm) which should remain at ± 0.15 in. (0.38 mm).

	@ Dia. <1.500 in. (<38.1 mm)	@ Dia. >1.500 in. (>38.1 mm)
Diameter (D) Tolerance	$\pm .015$ in. (0.38 mm)	± 0.10 in. (0.25 mm) per each 1.000 in. (25.4 mm) of Dia.

b/t RATIO

The following ring width to thickness ratios should not be exceeded for conventional ring manufacturing processes:

carbon steel	4
chrome silicon steel	3
stainless steel	4

Wire with b/t ratios greater than 5 cannot be cold worked from round wire on conventional equipment and is typically purchased preformed at a significant material price penalty.

RING THICKNESS TOLERANCE

The ring thickness tolerance should be $\pm .002$ in. (0.05 mm). To maintain a statistically controlled tolerance of $\pm .001$ in. (0.025 mm), secondary grinding is required adding significant expense.

Section Thickness (t)	$\pm .002$ in. (0.05 mm) as formed	$\pm .001$ in. (0.025 mm) with secondary grinding
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RING SECTION RADIAL WIDTH TOLERANCE

The ring section radial width tolerance should be $\pm .004$ in. (0.102 mm) minimum.

GAP WIDTH TOLERANCE

External rings are usually specified with a linear free gap dimension. The minimum tolerance is dependent on the ring's diameter tolerance and determined by multiplying the ring's diameter tolerance by π . (Linear width is negligibly different than the actual arc length and is more practical to measure.)

Internal rings are sometimes specified with an installed linear gap dimension that allows a minimum of .039 in. (1.00 mm) clearance between ring end tips during installation. (See page 16 for determining the minimum gap on an example problem.) The ring gap is typically checked by holding the ring diameter to a specific gauge dimension and measuring the gap width within a tolerance of .125 in. (3.18 mm) or greater. If a free gap dimension is specified, tolerances would be the same as for external rings.

RING FLATNESS

The maximum free helix should equal the maximum ring thickness. Anything less is difficult to maintain for most Statistical Process Control requirements. Dish tolerances are usually specified as .005 in. (0.13 mm) over maximum material section thickness when measured under parallel plates exerting a 10 lb. (4.5 kg) load.

MATERIAL HARDNESS

If material hardness on a coiled ring is given, the values should be specified within the following ranges:

ASTM-A227 hard drawn, Rockwell "C" 40-50
ASTM-A229 oil tempered, Rockwell "C" 43-53
ASTM-A401 oil tempered chrome silicon, Rockwell "C" 48-58

Hardness values are generally not required on the blueprint, since they are often covered within the customer's material specifications. However, it is sometimes appropriate to specify the hardness range of the finished ring in order to distinguish between materials. Tensile testing is not possible once the material has been coiled.

CORRELATION BETWEEN ROCKWELL HARDNESS AND TENSILE STRENGTH

In a ring application, tensile strength is the important factor. Raw material is purchased to tensile strength values which cannot be checked after the wire is coiled. Since tensile testing of coiled rings is not possible, some customers specify hardness ranges on their retaining ring designs. Using the tolerance ranges shown above should insure adequate material performance and property characteristics.

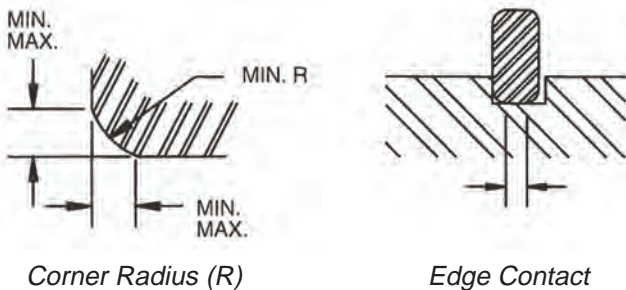
DESIGN GUIDELINES

MATING COMPONENTS

Thrust capacity is dependent on ring and groove characteristics, and the clearances between mating components.

RING CORNER RADIUS/CHAMFER

Ring corners are seldom a true radius due to metal flow during the transition from round wire to shaped wire. The corner break should be dimensioned as shown in the illustration to provide corner zone control. Corners must be equal in configuration, with .010 in. (0.25 mm) tolerance and at least 2/3 of the ring's edge radially contacting the groove.

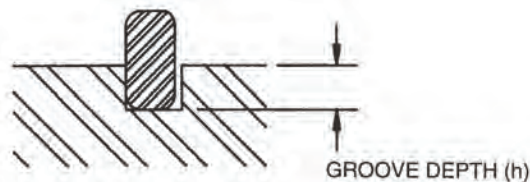


DIAMETER FIT

A .020 to .050 in. (0.50 mm to 1.27 mm) interference fit should be maintained under most conditions between the ring diameter and the groove diameter. Greater interference will not result in greater thrust capability. Some designers use 1% of the ring diameter to determine the groove interference.

RADIAL COVERAGE

Groove depth (h) should be 1/3 to 1/2 of the ring's radial width (b). This provides optimum ring stability in applications with high shear forces.



Radial Coverage

GROOVE WIDTH

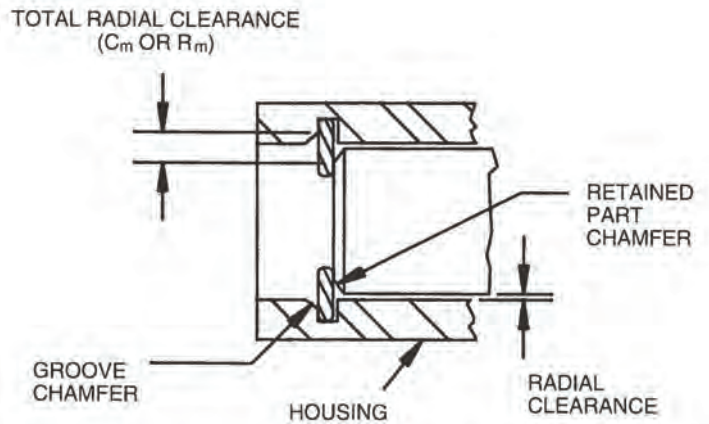
Groove width (x) should be 1.143 times the mean ring section thickness (t) dimension. This provides sufficient clearance for assembly while minimizing ring tipping in unstable situations.

SHOULDER WIDTH

Shoulder width (w) should be greater than four times the groove depth (h) for optimum groove thrust capacity and support. When width to groove depth ratios (w/h) are less than four, groove thrust capacity is adjusted with correction factors shown on page 14.

RADIAL CLEARANCE

Mating components retained by rings should have minimal radial clearance, minimal ring and groove and groove corner radii/chamfer, and minimal corner breaks. When the ring is axially loaded, the greater the radial distance from the support of the groove, the greater the ring deflection will be, lowering thrust capabilities. Radial clearance must be considered in the calculation of maximum radius/chamfer as part of the maximum corner break.



Internal Ring Assembly Cross Section

MAXIMUM STRESS LEVEL

Maximum bending stress occurs during ring installation. To avoid plastic deformation, the stress level on internal rings should not exceed 100% of the minimum material tensile strength, and on external rings 80%. For maximum set resistance, rings should be stress relieved to remove residual stresses produced during the ring forming operation.

CUTOFF CONFIGURATIONS

Because some cutoff configurations are more costly than others, it is important to determine the optimum design for each application. Any two of the configurations can be provided on the same ring (opposing at the gap) to meet various design or cost criteria.

- Full radius cuts or those having long shear lengths require high cutting loads and are susceptible to distortion and burning.

- Gap opening should be dimensioned as the minimum linear distance between gap ends.
- When both ends have angled cuts, the included angle should be specified when possible.

Refer to the following illustrations for specific design guidelines.

TYPICAL CUTOFF CONFIGURATIONS

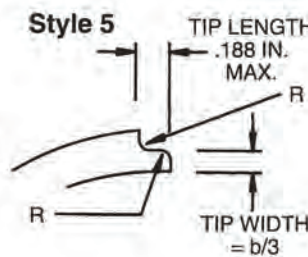
Style 1



Straight

Internal/External Ring
Optional
Primary Use: Any application where special disassembly aids are not required

Style 5



Outside Butterfly

Internal Ring
Optional
Primary Use: Disassembly and/or identification

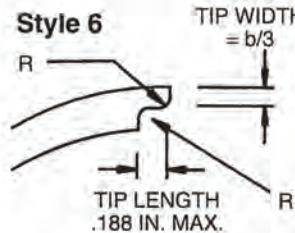
Style 2



Outside Angle $30^\circ \pm 5^\circ$

Internal Ring
Preferred
Primary Use: Disassembly and/or identification

Style 6



Inside Butterfly

External Ring
Optional
Primary Use: Disassembly and/or identification

Style 3



Inside Angle $30^\circ \pm 5^\circ$

External Ring
Preferred
Primary Use: Disassembly and/or identification

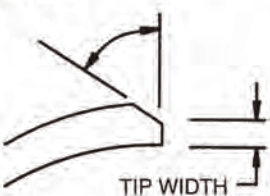
Style 7



Full Radius

Internal Ring
Not Recommended
Primary Use: Identification

Style 4



Angle/Straight

Internal Ring
Not Recommended
Primary Use: Identification

Style 8



Notched

Internal Ring
Primary Use: Disassembly
Consult Peterson Spring Engineering before specifying this type of configuration.

Style 9



Holes

Internal/External Rings
Primary Use: Disassembly
Consult Peterson Spring Engineering before specifying this type of configuration.

MATERIAL SPECIFICATIONS

GENERAL PROPERTIES OF COMMON MATERIALS USED IN RETAINING RING APPLICATIONS

COMMON RING WIRE	WIRE DIAMETER (d) IN. (MM)	ULTIMATE TENSILE STRENGTH (S _T) RANGE psi (MPa)	APPROXIMATE SHEAR LENGTH psi (MPa)	MODULUS OF ELASTICITY (E) psi (Mpa)	FINISHED RING HARDNESS (ROCKWELL "C" SCALE) HRC	MAXIMUM RECOMMENDED SERVICE TEMPERATURE °F (°C)
Hard Drawn Carbon Steel ASTM-A227	.080 in. (2.03 mm)	227-261 x 10 ³ (1565-1800)	140,000 (965)	30 x 10 ⁶ (207 x 10 ³)	40-50	302 (150)
	.120 in. (3.05 mm)	210-241 x 10 ³ (1448-1662)				
	.177 in. (4.50 mm)	195-225 x 10 ³ (1345-1551)				
Oil Tempered Carbon Steel ASTM-A229	.080 in. (2.03 mm)	235-265 x 10 ³ (1620-1827)	150,000 (1034)	30 x 10 ⁶ (207 x 10 ³)	43-53	320 (160)
	.120 in. (3.05 mm)	220-250 x 10 ³ (1517-1724)				
	.177 in. (4.50 mm)	200-225 x 10 ³ (1379-1551)				
Oil Tempered Chrome Silicon Alloy Steel ASTM-A401	.080 in. (2.03 mm)	285-310 x 10 ³ (1965-2137)	165,000 (1138)	30 x 10 ⁶ (207 x 10 ³)	48-58	482 (250)
	.120 in. (3.05 mm)	275-300 x 10 ³ (1896-2068)				
	.177 in. (4.50 mm)	260-285 x 10 ³ (1793-1965)				
Stainless Steel ASTM-A313	.080 in. (2.03 mm)	241-275 x 10 ³ (1662-1896)	120,000 (827)	28 x 10 ⁶ (193 x 10 ³)	Approx. 25-35	400 (205)
	.120 in. (3.05 mm)	222-275 x 10 ³ (1531-1896)				
	.177 in. (4.50 mm)	198-228 x 10 ³ (1365-1572)				

COMMON GROOVE MATERIAL	APPROXIMATE ULTIMATE TENSILE STRENGTH psi (MPa)	APPROXIMATE YIELD STRENGTH psi (MPa)	APPROXIMATE HARDNESS BRINELL SCALE - Bhn ROCKWELL "C" SCALE - HRC
Low-Mild Carbon Steel	67 x 10 ³ (462)	45 x 10 ³ (310)	150 Bhn
Hardened Carbon Steel	180 x 10 ³ (1241)	162 x 10 ³ (1117)	45 min. HRC
Cast Steel	100 x 10 ³ (690)	80 x 10 ³ (552)	360 Bhn
Grey Iron	50 x 10 ³ (345)	None - Use Tensile Value	260 Bhn
Ductile Iron	75 x 10 ³ (517)	50 x 10 ³ (345)	225 Bhn
Cast Aluminum	32 x 10 ³ (221)	24 x 10 ³ (165)	120 Bhn

DESIGN FORMULAE

INTRODUCTION

Retaining rings are essentially circular, slender beams that are laterally stable and deflection loaded in pure bending. Various design approaches are used to engineer rings for given applications and they are all based on conventional engineering mechanics principles such as Hooke's Law and Castigliano's Theorem.

The following formulae and procedures are based on established theoretical and empirically derived guidelines, best suited for the range of retaining rings, commonly used by customers of Peterson Spring.

First the equations for radial load and stress are noted. Along with the equations for uniform section rectangular wire rings, formulae for round wire rings are also given. Although the vast majority of retaining rings are manufactured from rectangular uniform section wire, round wire rings are sometimes used as spacers or retaining rings when thrust loads are low.

During assembly, the expansion or contraction load on most rings is applied at 90° from the center of the gap. Automated or manual assembly methods typically utilize some type of tapered tool to guide the ring into a bore or over a shaft. The area of greatest force is therefore applied 90° from the center of the gap. The second assembly method applies the expansion or contraction load at the gap, usually through manual methods utilizing special pliers or other tools to hold the ring ends. External rings with extremely wide gaps such as "C" rings are designed to be pushed radially over a shaft groove spreading the ring ends in the process. Regardless of the techniques used for assembly, the area of highest ring bending stress occurs 180° from the center of the gap.

Following the radial load and stress equations are the stress correction factors for both the internal and external ring. Next, thrust calculation formulae are given, followed by the rotational speed capacity equation for external rings.

TERMS

Linear dimensions of the following terms use inches (mm); force characteristics use lbs. (Newtons); strength characteristics use psi (MPa).

- A** – Ring cross sectional area $\left(t \times b \text{ or } \frac{\pi d^2}{4} \right)$
- b** – Ring radial section width
- b/t** – Ring radial width to thickness ratio
- C_m** – Total radial clearance allowed when mating parts have chamfers
- CF** – Correction factor for maximum groove thrust based on the w/h ratio
- CF_I** – Stress correction factor for internal rings
- CF_E** – Stress correction factor for external rings
- D** – Mean diameter: Internal ring (outer diameter – b)
External ring (inner diameter + b)
- D_G** – Groove diameter
- D_H** – Housing diameter
- D_S** – Shaft diameter
- d** – Wire diameter
- D/b** – Ring index (rectangular wire)
- D/d** – Ring index (round wire)
- E** – Modulus of elasticity
- F** – Deflection at the gap of a ring
- f** – Deflection 90° from center of gap
- G** – Ring free gap
- h** – Groove depth
- I** – Moment of inertia $\left(\frac{t \times b^3}{12} \text{ or } \frac{\pi \times d^4}{64} \right)$
- I.D.** – Ring inside diameter
- N** – Rotational speed in revolutions per minute
- O.D.** – Ring outside diameter
- P_G** – Load at gap of ring during gap deflection
- P_g** – Load 90° from center of gap
- R** – Corner Radius
- R_m** – Total radial clearance allowed when mating parts have radii
- S_G** – Stress for rings expanded at the gap
- S_g** – Stress for rings expanded 90° from center of gap
- S_s** – Shear strength of ring material
- S_T** – Ultimate tensile strength of ring material
- S_y** – Yield strength of groove material
- T** – Static ring thrust capacity
- T_G** – Static groove thrust capacity
- T_C** – Static ring thrust with maximum allowable corner break or chamfer
- T_R** – Static ring thrust with maximum allowable corner radius
- t** – Ring thickness
- V** – External ring radial interference (D_G – I.D.)
- w** – Shoulder width
- x** – Groove width
- y,z** – Empirically derived variable

DESIGN FORMULAE

RADIAL LOAD AN DEFLECTION STRESS

Radial Load

	RECTANGULAR WIRE	ROUND WIRE
90° FROM CENTER OF THE GAP	$P_g = \frac{4Et_b^3f}{3\pi D^3}$	$P_g = \frac{Ed^4f}{4D^3}$
AT THE GAP	$P_G = \frac{4Et_b^3F}{18\pi D^3}$	$P_G = \frac{Ed^4f}{24D^3}$

Deflection Stress

	RECTANGULAR WIRE	ROUND WIRE
90° FROM CENTER OF THE GAP	$S_g = \frac{fE}{b} [(CF_I) \text{ or } (CF_E)]$	$S_g = \frac{fE}{d} [(CF_I) \text{ or } (CF_E)]$
AT THE GAP	$S_G = \frac{FE}{3b} [(CF_I) \text{ or } (CF_E)]$	$S_G = \frac{FE}{3d} [(CF_I) \text{ or } (CF_E)]$

STRESS CORRECTION FACTORS

Internal Retaining Rings

$$CF_I = [(D/b) y]^* + z$$

D/b	y	z
†7.500 to < 8.075	-5.714 x 10 ⁻³	4.876 x 10 ⁻²
8.075 to < 8.600	-3.810 x 10 ⁻³	4.876 x 10 ⁻²
8.600 to < 9.225	-3.200 x 10 ⁻³	4.352 x 10 ⁻²
9.225 to < 10.100	-2.285 x 10 ⁻³	3.509 x 10 ⁻²
10.100 to < 10.575	-2.105 x 10 ⁻³	3.326 x 10 ⁻²
10.575 to < 11.150	-1.739 x 10 ⁻³	2.939 x 10 ⁻²
11.150 to < 11.850	-1.429 x 10 ⁻³	2.593 x 10 ⁻²
11.850 to < 12.675	-1.212 x 10 ⁻³	2.336 x 10 ⁻²
12.675 to < 13.550	-1.143 x 10 ⁻³	2.249 x 10 ⁻²
13.550 to < 14.550	-1.000 x 10 ⁻³	2.055 x 10 ⁻²
14.550 to < 16.050	-6.667 x 10 ⁻⁴	1.570 x 10 ⁻²
16.050 to < 16.925	-5.714 x 10 ⁻⁴	1.417 x 10 ⁻²
16.925 to < 18.000	-4.651 x 10 ⁻⁴	1.237 x 10 ⁻²
18.000 to < 19.500	-3.300 x 10 ⁻⁴	1.000 x 10 ⁻²
19.500 to < 21.000	-2.000 x 10 ⁻⁴	7.400 x 10 ⁻³
21.000 to < 22.500	-6.667 x 10 ⁻⁵	4.600 x 10 ⁻³
22.5 or greater	-4.000 x 10 ⁻⁵	4.000 x 10 ⁻³

External Retaining Rings

$$CF_E = [(D/b) y]^* + z$$

D/b	y	z
†7.500 to < 8.100	-8.889 x 10 ⁻³	9.600 x 10 ⁻²
8.100 to < 8.375	-7.273 x 10 ⁻³	7.560 x 10 ⁻²
8.375 to < 8.688	-6.400 x 10 ⁻³	7.560 x 10 ⁻²
8.688 to < 9.050	-5.517 x 10 ⁻³	7.560 x 10 ⁻²
9.050 to < 9.500	-4.444 x 10 ⁻³	5.822 x 10 ⁻²
9.500 to < 10.050	-3.636 x 10 ⁻³	5.055 x 10 ⁻²
10.050 to < 10.686	-3.141 x 10 ⁻³	4.562 x 10 ⁻²
10.686 to < 11.550	-2.313 x 10 ⁻³	3.673 x 10 ⁻²
11.550 to < 12.675	-1.777 x 10 ⁻³	3.053 x 10 ⁻²
12.675 to < 14.450	-1.126 x 10 ⁻³	2.228 x 10 ⁻²
14.450 to < 15.700	-8.000 x 10 ⁻⁴	1.756 x 10 ⁻²
15.700 to < 17.650	-5.120 x 10 ⁻⁴	1.305 x 10 ⁻²
17.650 to < 19.000	-3.700 x 10 ⁻⁴	1.054 x 10 ⁻²
19.000 to < 23.000	-1.250 x 10 ⁻⁴	5.875 x 10 ⁻³
23.0 or greater	-1.000 x 10 ⁻⁴	5.300 x 10 ⁻³

*Substitute D/d using round wire.

†If less than 7.500, consult Peterson Spring Engineering

DESIGN FORMULAE

THRUST CALCULATIONS AND THRUST LIMITING FACTORS

Thrust limitations can be calculated from the following formulae. If the shoulder width is less than the recommended ratio of four times the groove depth, the maximum static groove thrust is adjusted.

Maximum Thrust Calculations for Retaining Rings & Grooves

	Static Thrust @ $w/h \geq 4$	Adjusted Thrust Due to $w/h < 4$
Internal Ring	$T = .3 (D_H S_S \pi t)$	-
External Ring	$T = .25 (D_S S_S \pi t)$	-
Internal Groove	$T_g = .6 (D_H S_y \pi h)$	$T_g = [.6 (D_H S_y \pi h)] / CF^*$
External Groove	$T_g = .5 (D_S S_y \pi h)$	$T_g = [.5 (D_S S_y \pi h)] / CF^*$

*Where CF is calculated from the following equations:

w/h	CF
1.0 to 1.5	$(-3.200 \times w/h) + 7.490$
>1.5 to 2.0	$(-1.550 \times w/h) + 5.054$
>2.0 to 2.5	$(-0.948 \times w/h) + 3.856$
>2.5 to 3.0	$(-0.600 \times w/h) + 2.997$
>3.0 to 3.5	$(-0.260 \times w/h) + 1.982$
>3.5 to 4.0	$(-0.156 \times w/h) + 1.557$
>4.0	Has Negligible Influence

Total Radial Clearance and Corner Conditions – Total radial clearance affects the thrust capacity of an assembly and must be considered when chamfers, radii, or generous clearances are present. To calculate the maximum total radial clearance allowed for an assembly, the following formulae can be utilized. Corresponding corrected thrust capacity formulae follow.

Internal Ring:

Inch

$$R_m = [((t \times h) 5.630) + .04479]$$

$$C_m = [((t \times h) 4.388) + .04222]$$

Metric

$$R_m = [((t \times h) 5.630 (1.55 \times 10^{-3})) + .04479] 25.4$$

$$C_m = [((t \times h) 4.388 (1.55 \times 10^{-3})) + .04222] 25.4$$

External Ring:

Inch

$$R_m = [((t \times h) 6.443) + .05267]$$

$$C_m = [((t \times h) 3.862) + .03154]$$

Metric

$$R_m = [((t \times h) 6.443 (1.55 \times 10^{-3})) + .05267] 25.4$$

$$C_m = [((t \times h) 3.862 (1.55 \times 10^{-3})) + .03154] 25.4$$

Corrected Thrust Capacity – The following formulae give the maximum static thrust capacity of the ring when factored at the maximum total radial clearance, R_m or C_m .

Internal Ring:

Inch

$$T_R = [((D_H \times t) 0.106) + .0708] T$$

$$T_C = [(-0.060 (D_H \times t) + 0.230] T$$

Metric

$$T_R = [((D_H \times t) 0.106 (1.55 \times 10^{-3})) + 0.708] T$$

$$T_C = [(-0.060 (D_H \times t) (1.55 \times 10^{-3})) + 0.230] T$$

External Ring:

Inch

$$T_R = [((D_S \times t) 0.1625) + 0.669] T$$

$$T_C = [((D_S \times t) 0.1625) + 0.669] T$$

Metric

$$T_R = [((D_S \times t) 0.1625 (1.55 \times 10^{-3})) + 0.669] T$$

$$T_C = [((D_S \times t) 0.1625 (1.55 \times 10^{-3})) + 0.669] T$$

Surge Loading and Other Concerns – Surge loading (without impact) can be compensated for by using 50% of the preceding thrust calculations. Further reductions in thrust capacity are caused by impact and vibration loads, large gap widths, and interrupted cuts or splined groove shoulders. Structural integrity of the grooved component is also affected by the reduced wall thickness under the groove as well as stress concentrations in the groove corners. Dynamic testing of an actual assembly or system is recommended to verify calculated values.

MAXIMUM ROTATIONAL SPEED

Centrifugal force affects external rings only. If high rotational speeds are expected in an installation, the following formula is generally recognized as an adequate guideline for determining the ring's maximum revolutions per minute (N). Use English units only with this formula.

$$N = 5.5 \times 10^6 \left(\frac{V \times I}{A \times D^5} \right)^{1/2}$$

*Derived from English units.

DESIGN EXAMPLE

SOME BACKGROUND CONSIDERATIONS

Since all rings are unique to their specific application, there are diverse design approaches. Practically speaking, the retaining ring/groove is usually the last consideration evaluated, with the majority of the assembly already designed. When the designer reaches the stage where the assembly dimensional stackups are established, the space where the retaining ring/groove will function is ready to be evaluated.

In many cases there will be a shoulder on one side of the groove. As a rule, the ring groove has considerably less thrust capacity than the retaining ring. The supporting shoulder dimensions will have a major impact on the groove thrust capacity. As previously noted in the **Thrust Calculations** section on page 14, the shoulder width should be at least four times as thick as the groove depth.

Evaluate the space envelope and try to design the groove geometry to give the heaviest shoulder possible and still maintain an adequate groove depth. The groove thrust capacity can then be calculated using the formulae given previously in the text. If the groove thrust capacity is adequate for the application, proceed to design the retaining ring. If the groove thrust capacity is not adequate, evaluate the assembly stack ups to provide more material in the shoulder and perhaps deepen the groove.

In some cases a shoulder width ratio of four cannot be maintained. If that occurs, make appropriate concessions and determine the maximum thrust capacity possible within the space envelope using the appropriate formulae.

If adequate groove geometry with enough thrust capacity cannot be established, a redesign of the assembly will be necessary.

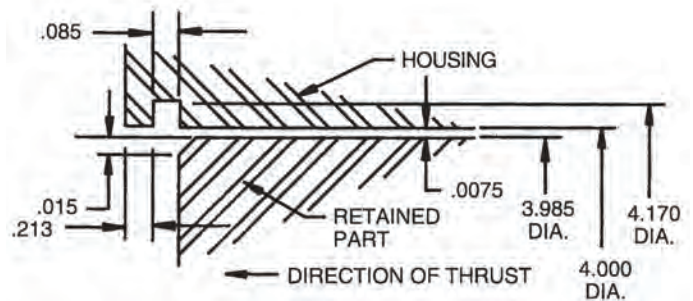
If an existing groove geometry is provided, a large part of the work is already done. However, still verify the groove thrust capacity to assure that the retaining ring design is being based on sufficient groove geometry.

EXAMPLE PROBLEM

In this example, the housing and groove dimensions have already been established and the task is to design an internal uniform constant section coiled ring.

GIVEN

- Housing bore diameter (D_H) = 4.000 in.
- Housing groove diameter (D_G) = 4.170 in.
- Shoulder width (w) = .213 in.
- Groove width (x) = .085 in.
- Retained part diameter (D_S) = 3.985 in.
- Retained part chamfer = .015 in. x 45°
- Thrust load exerted against retaining ring = 2,000 lbs.



Assembly Conditions

FIND

Appropriate ring for this application

SOLUTION – Dimensional and Performance Evaluations

DIMENSIONAL EVALUATION

- Establish the appropriate ring thickness (t) by dividing the groove width (x) by 1.143 (see page 9).

$$t = x \div 1.143$$

$$t = .085 \text{ in.} \div 1.143 = .074$$

- Establish the approximate ring radial width (b) by multiplying the groove depth (h) by three.

$$b = h \times 3 \text{ where } h = \frac{1}{2} (D_G - D_H)$$

$$h = \frac{1}{2} (4.170 \text{ in.} - 4.000 \text{ in.}) = .085 \text{ in.}$$

$$b = .085 \text{ in.} \times 3 = .255 \text{ in.}$$

Therefore, for the given groove condition,

$$b/t = .255/.074 = 3.45$$

DESIGN EXAMPLE

- Using the b/t value to select material, SAE 1065 hard drawn or oil tempered steel would be appropriate. Hard drawn steel is commonly specified on lower stressed internal rings with the higher strength oil tempered allowed as an option. The blueprint would specify a Rockwell hardness of “C” 40-50 at finish for hard drawn, and 43-53 for oil tempered.
- Establish the free O.D. for the ring by using 1% of installed diameter for the interference fit as noted in the **Design Guidelines** section on page 9. One percent of the groove diameter is .042. The .042 in. is then added to the groove diameter to give a minimum free O.D. of 4.212 in. As noted in the **Guidelines** section on page 8, the free diameter tolerance should be $\pm .010$ in. for each inch of ring diameter, so a total of .084 in. diameter tolerance is needed. The .084 in. total diameter tolerance added to the established ring minimum free O.D. gives a maximum free O.D. of 4.296 in. Therefore, the free O.D. range is from 4.212 in. to 4.296 in.

$$\begin{aligned} \text{Minimum free O.D.} &= 1\% (4.170 \text{ in.}) + 4.170 \text{ in.} \\ &= 4.212 \text{ in.} \end{aligned}$$

$$\begin{aligned} \text{Total Tolerance} &= \pm (4.212 \text{ in.} \times .010) \\ &= \pm .042 \text{ in. or } .084 \text{ in.} \end{aligned}$$

$$\begin{aligned} \text{Maximum free O.D.} &= 4.212 \text{ in.} + .084 \text{ in.} \\ &= 4.296 \text{ in.} \end{aligned}$$

- The next consideration would be the ring gap. As this is an internal ring, an installed gap will be specified with the installed diameter being the groove diameter. The change in diameter of the ring during installation from the bore diameter to the groove diameter is 0.170 in. Therefore, the change in gap dimension is .534 in. Since a minimum of .039 in. clearance between the ring tips is recommended during installation, the minimum installed end gap is .573 in.

$$\text{Diameter change} = 4.170 \text{ in.} - 4.000 = .170 \text{ in.}$$

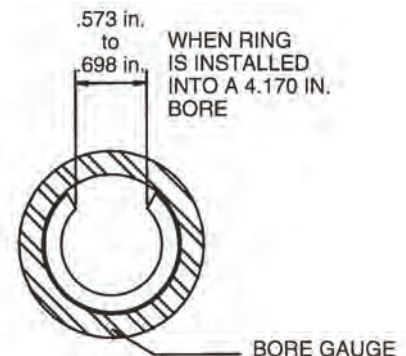
$$\text{Ring gap change} = .170 \text{ in.} \times \pi = .534 \text{ in.}$$

$$\begin{aligned} \text{Minimum installed ring gap} &= .534 \text{ in.} + .039 \text{ in.} \\ &= .573 \text{ in.} \end{aligned}$$

- Maximum installed ring gap is established by adding .125 in. to the minimum installed gap. See the **Design Guidelines** section on page 8.

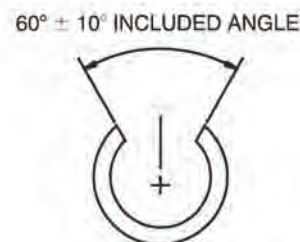
$$\begin{aligned} \text{Maximum installed ring gap} &= .573 \text{ in.} + .125 \text{ in.} \\ &= .698 \text{ in.} \end{aligned}$$

The above values can be shown on a blueprint as follows:



Installed Gap

- Cutoff configurations for the gap can now be selected. From the **Design Guidelines** section on page 10, the 30° outside angle is the preferred configuration for an internal ring. Both ring tips will be specified as outside angle cuts for disassembly purposes. The angle on the configurations should therefore be specified as an included angle with a $\pm 10^\circ$ tolerance.



Cutoff Configuration

PERFORMANCE EVALUATION

At this point, the ring is basically designed from the dimensional standpoint and must be evaluated for function in the assembly. A major consideration is the stress induced in the ring during assembly. If the stress is excessive, the ring will “set,” that is, it will plastically deform and reduce in diameter. If the reduced ring diameter is less than the groove diameter, the function of the ring will be greatly impaired.

DESIGN EXAMPLE

- Select the appropriate stress calculation formula and correction factors from page 13 and check the installation stress.

$$S_g = \frac{fE}{b} (CF_i)$$

Solving for f and CF_i:

f = Maximum Free O.D. – Housing Diameter (DH)

f = 4.296 in. - 4.000 in.

= .296 in

$$(CF_i) = [(D/b) y] + z$$

D = Mean ring O.D. – b

D = ½ (4.212 in. + 4.296 in.) - .255 = 3.999 in.

D/b = $\frac{3.999 \text{ in.}}{.255} = 15.682$

Therefore, y = -6.667×10^{-4} and z = 1.570×10^{-2}

$$CF_i = [(15.682) - 6.667 \times 10^{-4}] + 1.570 \times 10^{-2}$$

$$= 5.245 \times 10^{-3}$$

Therefore, solving for S_g:

$$S_g = \left[\frac{(.296 \text{ in.})(30 \times 10^6 \text{ psi})}{.255 \times 10^{-3}} \right] (5.245 \times 10^{-3}) = 182,650 \text{ psi}$$

This stress level falls below the material's tensile strength, thereby indicating an acceptable design.

- Next evaluate the maximum calculated radial load exerted by the ring during the assembly process. The radial load is determined using the formula from page 13:

$$P_g = \frac{4Etb^3f}{3\pi D^3}$$

$$P_g = \frac{4(30 \times 10^6 \text{ psi})(.074 \text{ in.})(.255 \text{ in.})^3(.296 \text{ in.})}{3\pi(3.999 \text{ in})^3}$$

= 72.3 lbs.

- The next concern would be the thrust capacity of the ring. Using the formula on page 14:

$$T = .3(D_H S_y \pi T)$$

$$T = .3(4.00 \text{ in.})(140 \times 10^3 \text{ psi})(\pi)(.074 \text{ in.}) = 39,056 \text{ lbs.}$$

**From the table on page 11 for hard drawn material*

The sudden surge dynamic thrust capacity would be 50% of the above figure or 19,528 lbs.

The calculated ring sudden surge capacity is greater than the system thrust so the ring is adequately designed.

19,528 lbs. > 2,000 lbs.

- Since the entire system is being evaluated, the designer would next calculate the thrust capacity for the groove using the formula from page 14:

$$T_g = .6(D_H S_y \pi h)$$

First check the shoulder width backing up the ring. In the specifications, that figure is .213 in. Determine if the shoulder width (w) to groove depth (h) ratio is equal to or greater than the recommended ratio of 3 minimum. The groove depth is .085 in., so the shoulder width ratio is:

$$w/h = .213/.085 = 2.5$$

Since w/h is less than the recommended ratio of 4, calculate the groove thrust capacity from the adjusted thrust formula on page 14:

$$T_g = \frac{[.6(D_H S_y \pi h)]}{CF}$$

In reviewing the adjusted thrust formula, note that as a first step the CF or correction factor must first be calculated from the table, also on page 14. CF would then be calculated:

$$CF = (-0.948 \times 2.5) + 3.856 = 1.486$$

Substituting into the internal groove thrust equation:

$$T_g = \frac{[.6(4.000 \text{ in.})(45 \times 10^3 \text{ psi})(\pi)(.085 \text{ in.})]}{1.486}$$

$$= 19,408 \text{ lbs.}$$

**Cold rolled mild steel yield strength from page 11 (T_y).*

DESIGN EXAMPLE

- As with the ring, the theoretical groove thrust capacity is greater than the system thrust exerted. However, since the retained part has a chamfer that is contacting the ring, the radial clearance will include both the .015 in. dimension of the chamfer and the .0075 in. radial wall clearance between the housing and retained part.

Total radial clearance = .015 in. + .0075 in. = .0225 in.

The effect of the total radial clearance will reduce the theoretical thrust capacity of the ring in the assembly. Accordingly, calculate the maximum allowed chamfer or radius which would include clearance between the components. This formula is also found on page 14:

$$C_m = [(t h) 4.388] + .0422]$$

$$C_m = [((.074)(.085)(4.388)) + .0422] = .070 \text{ in.}$$

Comparing the actual total radial clearance of .0225 in. to the calculated maximum total radial clearance of .070 in. verifies that the actual radial clearance is acceptable. When radial clearance is a concern, the corrected thrust capacity equation shown on page 14 is used:

$$T_c = [-0.060]D_H t) + .230] T$$

$$T_c = [(-0.060)(4.000 \text{ in.})(.074 \text{ in.}) + 230] * 19,408 \text{ lbs.} = 4,119 \text{ lbs.}$$

**In this case the dynamic sudden surge thrust load is used to represent the worst case mode.*

Since the maximum calculated radial clearance of .070 in. will have a calculated minimum thrust capacity of 4,119 lbs., be assured that the actual radial clearance will keep the system thrust capacity well above the actual thrust exerted by the system.

In summary, the retaining ring designed in this example is only one of several possible solutions. Occasionally, it will be necessary to vary ring parameters to fit a particular groove/assembly application or vary the groove conditions to accommodate the ring. This trial and error process of selecting various parameters allows alternative system designs for the same application.

Hong Kong Spring engineers welcome any inquiries; we can bring many years of experience to your particular design problem and help determine the most efficient and cost-effective solutions.

RING STANDARDS

The following standard ring data is published by Hong Kong Spring as a guideline for retaining ring and groove assemblies. The basis for this data is the *SAE-ASME USA Standard for General Purpose Rectangular Uniform Section Retaining Rings USA 5B27.5 – 1969*.

Hong Kong Spring can supply any of the following standard rings in quantities from a few pieces to hundreds of thousands. Our comprehensive stocks of round wire section and facilities for producing any size of rectangular section enable us to meet customer requirements on a just-in-time basis.

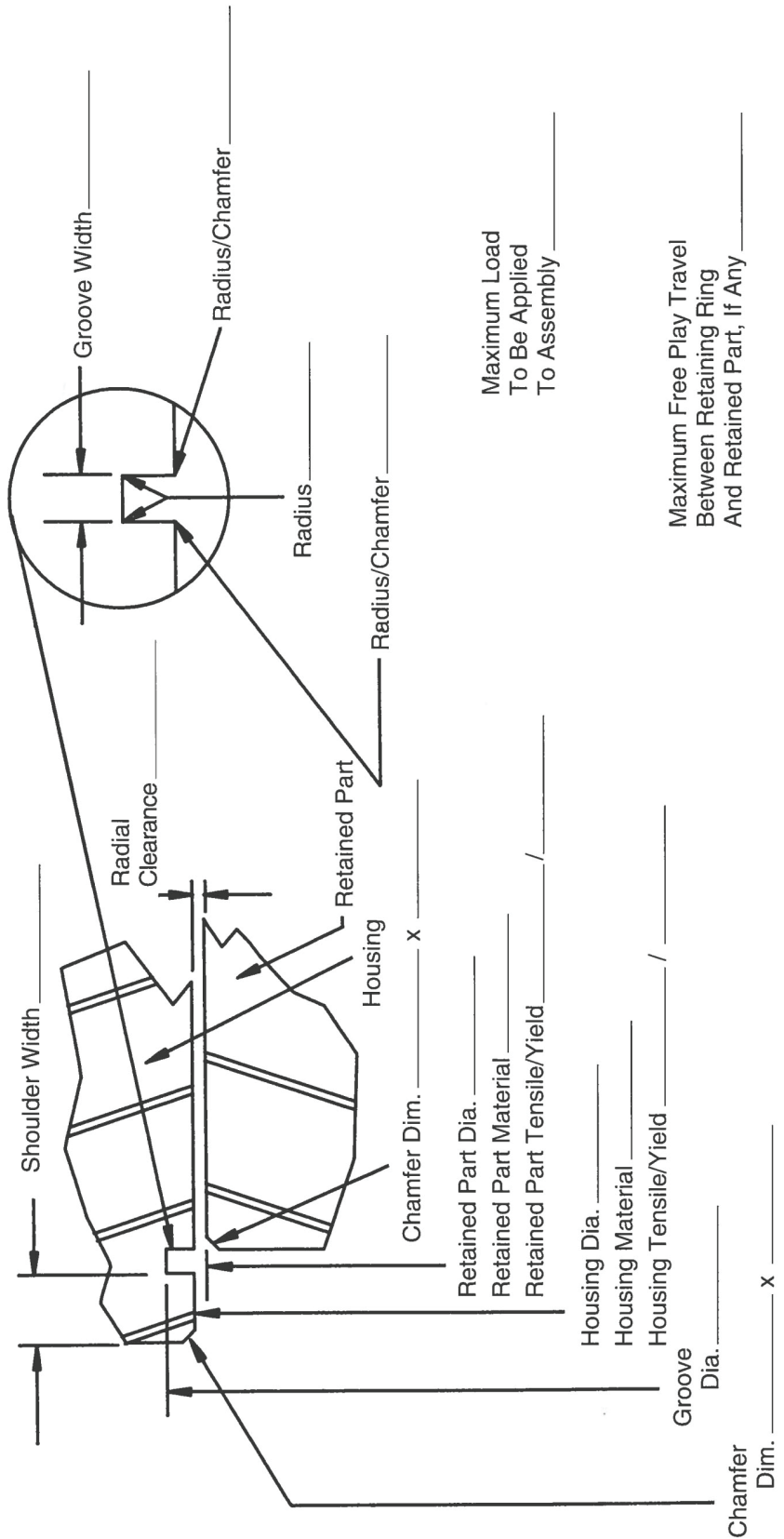
Our experienced design engineers can help you optimize a ring design for your specific application. If you require design assistance, fill out the forms on pages 22 and/or 23, and email: sales@pspring.com or fax to: (419) 867-8715. You will be contacted.

Hong Kong SPRING has over 50 years of experience in the design and manufacture of coiled retaining rings. Let us put our expertise to work for you.

For a FREE Technical Manual with retaining ring design data and engineering specifications, call (419) 867-8711.

Customer: _____
 Retaining Ring Part Number: _____
 Assembly Name/Nomenclature: _____
 B/P Date/Revision No.: _____
 Date: _____
 Customer Engineering Contact: _____
 Tel: _____ Fax: _____

INTERNAL RETAINING RING APPLICATION INFORMATION SHEET



EXTERNAL RETAINING RING APPLICATION INFORMATION SHEET

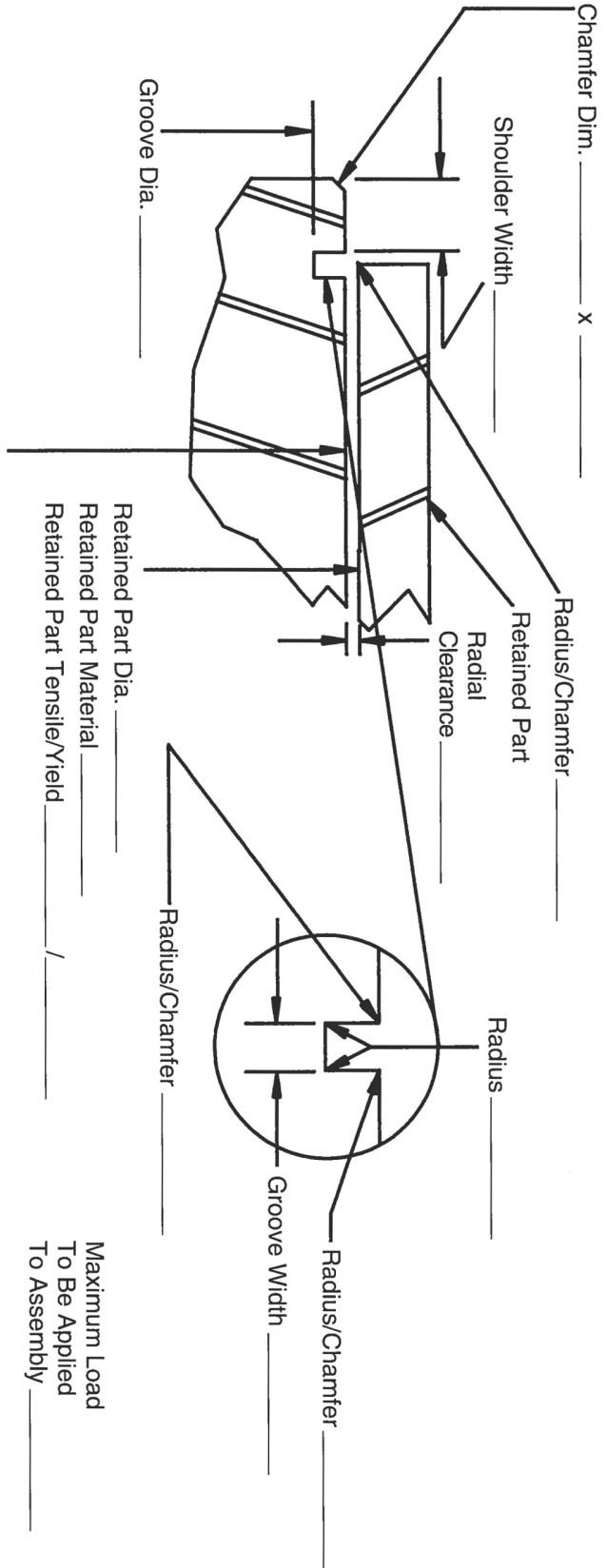
Customer: _____
 Retaining Ring Part Number: _____
 Assembly Name/Nomenclature: _____

B/P Date/Revision No: _____

Date: _____

Customer Engineering Contact: _____

Tel: _____ Fax: _____



Shaft Dia. _____
 Shaft Material _____
 Shaft Tensile/Yield _____ / _____
 Shaft Maximum RPM _____

Maximum Load
 To Be Applied
 To Assembly _____

Maximum Free Play Travel
 Between Retaining Ring
 And Retained Part, If Any _____

NOTES

NOTES

